


# Seismic hazard map of the Middle East

## Journal Article

**Author(s):**

Giardini, Domenico; [Danciu, Laurentiu](#) ; Erdik, Mustafa; Şeşetyan, Karin; Demircioğlu Tümsa M.; Akkar, Sinan; Gülen, Levent; Zare, Mehdi

**Publication date:**

2018-08

**Permanent link:**

<https://doi.org/10.3929/ethz-b-000254306>


**Rights / license:**

[In Copyright - Non-Commercial Use Permitted](#)

**Originally published in:**

Bulletin of Earthquake Engineering 16(8), <https://doi.org/10.1007/s10518-018-0347-3>

## Seismic hazard map of the Middle East

Domenico Giardini<sup>1</sup> · Laurentiu Danciu<sup>1</sup>  · Mustafa Erdik<sup>2</sup> ·  
Karin Şeşetyan<sup>2</sup> · Mine B. Demircioğlu Tümsa<sup>2,5</sup> · Sinan Akkar<sup>2</sup> ·  
Levent Gülen<sup>3</sup> · Mehdi Zare<sup>4</sup>

Received: 7 March 2018 / Accepted: 9 March 2018 / Published online: 16 March 2018  
© Springer Science+Business Media B.V., part of Springer Nature 2018

**Abstract** The collaborative project Earthquake Model of the Middle East (EMME, 2010–2015) brought together scientists and engineers from the leading research institutions in the region and delivered state-of-the-art seismic hazard assessment covering Afghanistan, Armenia, Azerbaijan, Cyprus, Georgia, Iran, Iraq, Jordan, Lebanon, Palestine, Pakistan, Syria and Turkey. Their efforts have been materialized in the first homogenized seismic hazard model comprising earthquake catalogues, mapped active faults, strong

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s10518-018-0347-3>) contains supplementary material, which is available to authorized users.

✉ Laurentiu Danciu  
laurentiu.danciu@sed.ethz.ch

Domenico Giardini  
domenico.giardini@erdw.ethz.ch

Mustafa Erdik  
erdik@boun.edu.tr

Karin Şeşetyan  
karin@boun.edu.tr

Mine B. Demircioğlu Tümsa  
minedemircioglu@gtu.edu.tr

Sinan Akkar  
sinan.akkar@boun.edu.tr

Levent Gülen  
lgulen@sakarya.edu.tr

Mehdi Zare  
mzare@iiees.ac.ir

<sup>1</sup> Department of Earth Sciences, ETH Zurich, Zurich, Switzerland

<sup>2</sup> Kandilli Observatory and Earthquake Research Institute, Boğaziçi University, Istanbul, Turkey

<sup>3</sup> Department of Geophysical Engineering, Sakarya University, Serdivan, Sakarya, Turkey

<sup>4</sup> International Institute of Earthquake Engineering and Seismology, Tehran, Iran

motions databank, ground motion models and the estimated ground motion values for various intensity measure types and relevant return periods (e.g. 475–5000 years). The reference seismic hazard map of the Middle East, depicts the mean values of peak ground acceleration with a 10% chance of exceedance in 50 years, corresponding to a mean return period of 475 years. A full resolution poster is provided with this contribution.

**Keywords** Seismic hazard map of the Middle East · EMME project · Probabilistic seismic hazard · Hazard assessment · Earthquake Model of the Middle East

## 1 Introduction

The Middle East region has a long history of destructive earthquakes, and seismic risk can severely affect our modern society, as shown by the tragic events of Izmit (Turkey, 1999), Bam (Iran, 2003), Kashmir (Pakistan, 2005), Van (Turkey, 2011) and Hindu Kush (Afghanistan, 2015). Minimization of the loss of life, property damage, and social and economic disruption due to earthquakes depends on reliable estimates of earthquake related hazards (e.g. ground shaking, tsunami, earthquake triggered landslides, soil liquefaction).

The collaborative project Earthquake Model of the Middle East (EMME, 2010–2015) brought together scientists and engineers from the leading research institutions in the region and delivers state-of-the-art seismic hazard assessment covering Afghanistan, Armenia, Azerbaijan, Cyprus, Georgia, Iran, Iraq, Jordan, Lebanon, Palestine, Pakistan, Syria and Turkey.

The EMME project generated homogeneous datasets that included seismo-tectonic regionalization, historical and instrumental earthquake catalogues (EMME Earthquake Catalogue of Middle East, ECME (Zare et al. 2014); seismically active faults (Gülen et al. 2014); models of deep seismicity in Hindu Kush (Pakistan) and subduction zones (e.g. Hellenic Subduction Arc, Cyprian Arc, Makran, Iran). Inherent uncertainties of quality and accuracy of earthquake sources and ground shaking data (Akkar et al. 2014) were incorporated by modelling alternative seismogenic source models (Danciu et al. 2017). Data driven techniques combined with sensitivity analyses were used when building the reference ground motion model (Danciu et al. 2016). A probabilistic framework was used to assess the seismic hazard, with aims to capture the range of epistemic uncertainties for model components and hazard results.

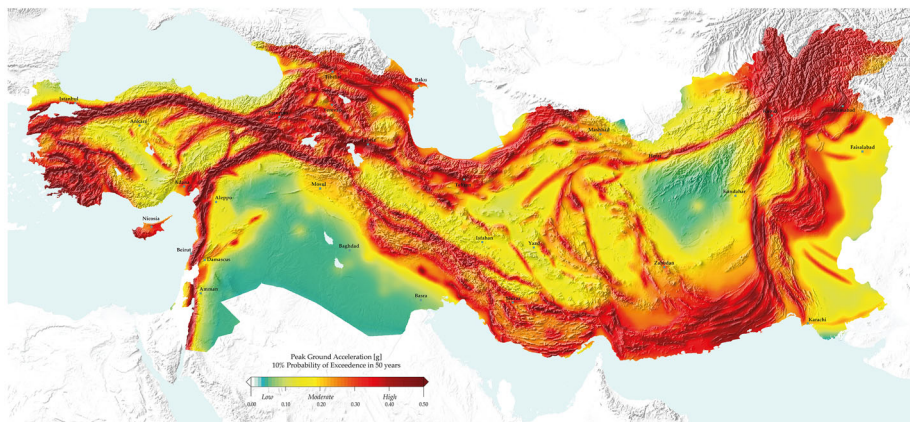
The EMME seismic hazard results described in detail by Şeşetyan et al. (2018) provide an overview of the potential shaking associated with future earthquakes in the Middle East. Both model elements (earthquake catalogues, seismogenic sources) and ground shaking estimates would serve in the future as input to develop strategies for seismic risk governance and earthquake resistant design for different applications—ranging from land use planning, improved building design and construction, adoption of modern building construction codes, emergency response preparedness plans, economic forecasts, housing and employment decisions, and other measures for risk mitigation.

<sup>5</sup> Present Address: Department of Civil Engineering, Gebze Technical University, Kocaeli, Turkey



# SEISMIC HAZARD MAP OF THE MIDDLE EAST

edited by D. Giardini, L. Dancos, M. Erdik, K. Sesetyan, M. Demircioglu, S. Akkar, L. Gülen and M. Zare, March 2018



**Fig. 1** Reference seismic hazard map of the Middle East depicting the mean values of peak ground acceleration (PGA) with 10% probability of being exceeded in 50 years (corresponding to a mean return period of 475 years) estimated for a rock soil ( $V_{s30} = 800$  m/s). The full resolution poster is available as an Electronic Supplement

## 1.1 Reference seismic hazard map of the Middle East

The seismic hazard map of the Middle East illustrated in Fig. 1, gives the estimated ground shaking levels (i.e. Peak Horizontal Ground Acceleration, PGA) on rock soil (shear wave velocity  $V_{s30} = 800$  m/s) to be reached or exceeded with a 10% probability in 50 years. This reference value represents the ground shaking to be expected during the human lifetime, corresponding to the average recurrence of such ground motions every 475 years, as prescribed by the national building codes for standard buildings in the region. In Fig. 1, the light blue to green colors depict comparatively low hazard ( $\text{PGA} \leq 10\%$  of the gravitational acceleration [g]), yellow to orange colors moderate hazard ( $10\%g < \text{PGA} \leq 30\%g$ ) and red to brown colors identify high hazard areas ( $\text{PGA} > 30\%g$ ). It is worth mentioning, that the reference seismic hazard map presented in Fig. 1 represents only one product out of the entire distribution of seismic hazard maps, hazard curves and uniform hazard spectra (Şeşetyan et al. 2018).

Without any doubt, the seismic hazard map for Middle East would serve as a reference for the region, given the regional compilation of harmonized databases of all parameters compulsory for probabilistic seismic hazard assessment; the application of state-of-the art procedures in all steps of the model building process; the quantification of epistemic uncertainties for model elements and hazard results; and transparency and open-access and availability of all data, methods and results ([www.efehr.org](http://www.efehr.org)).

To conclude, we encourage the adoption of the principles of data and model harmonization and use of transparent procedures for developing regional seismic hazard models. Nonetheless, the release of the regional hazard model would provide the opportunity for future research to mitigate the earthquake effects in the region.

A full resolution version of the official poster of the reference seismic hazard map for Middle East (Fig. 1) is provided as an (e) Electronic Supplement.

**Acknowledgements** We would like to acknowledge the collaborative efforts of the members of the EMME consortium as well as various local and regional researchers who have contributed to EMME-SHM14 by providing feedback to the hazard model and results. Among these are: Naweed Alam, Hanan Al-Nimry, Tawfiq Al-Yazjeen, Muheeb Awawdeh, Vakh dang Arabidze, Nick Arevadze, Arif Axfordov, Samvel Babayan, Ramy El-Khoury, Mohsen Ghafory-Ashtiany, Christis Chrysostomou, Jose Feghali, Nino Gaguadze, Guy Ghosn, Alexandre Gventcadze, Ebru Harmandar, Romy Helou, Gohar Hovahannisyanyan, Yiğit İnce, Rasheed Jaradat, Yaver Kamer, Sepideh Karimi, Adnan Khasawneh, Dinçer Köksal, Mukesh, Kumar, Nicholas Kyriakides, Sarosh H Lodi, Babak Mansouri, Orhan Can Özalp, Saud Quraan, S.F.A. Rafeeqi, Nino Sadradze, Ravi Sinha, Cüneyt Tüzün, Gianluca Valensise, Mohammad Reza Zolfaghari. We thank Marco Pagani, Damiano Monelli and Graeme Weatherill at Global Earthquake Model for their help and guidance throughout the project. We also thank Jochen Woessner (SHARE-Project), Stefano Parolai, Dino Bindi and Shahid Ullah (EMCA-Project) for their efforts on cross-border harmonization. Finally, we would like to express our gratitude to the OpenQuake IT development team, which provided constant and steady support during the EMME project. Namely, the support was granted by: Michele Simionato, Daniele Vigano and Lars Butler.

**Access to data and results** EMME products, data and results are available and documented through the web-platform of the European Facilities for Earthquake Hazard and Risk ([www.efehr.org](http://www.efehr.org))

**List of contributors** EMME Coordinators—Prof. D. Giardini, Department of Earth Sciences, ETH Zurich, Switzerland, Prof. M. Erdik, Bogazici University, Kandilli Observatory and Earthquake Research Institute, Istanbul, Turkey; EMME Project Manager—Seismic Hazard: Karin Şeşetyan, Boğaziçi University, Kandilli Observatory and Earthquake Research Institute, Istanbul, Turkey.

*EMME Seismic Hazard Integration Team:* Karin Şeşetyan, Boğaziçi University, Kandilli Observatory and Earthquake Research Institute, Istanbul, Turkey; Mine B. Demircioğlu-Tümsa, Boğaziçi University, Kandilli Observatory and Earthquake Research Institute, Istanbul, Turkey, Presently, Part time, Gebze Technical University, Department of Civil Engineering, Kocaeli, Turkey; Laurentiu Danciu, Swiss Seismological Service, at ETH Zurich, Switzerland.

*Main contributors*—Together with the editors of the poster, the main contributors to the seismic hazard map of the Middle East are: Shota Adamia, Mahmood Al-Qaryouti, Anooshiravan Ansari, Avetis Arakelyan, Ayşegül Askan, Mher Avanesyan, Hektor Babayan, Roberto Basili, Jean-Pierre Burg, Tamaz Chelidze, Raffi Durgaryan, Ata Elias, Hossein Hamzehloo, Khaled Hessami, Doğan Kalafat, Özkan Kale, Arkady Karakhanyan, Muhammad Asif Khan, Tahir Mamadli, Andrea N. Rovida, Mohammad Sayab, Massimiliano Stucchi, Nino Tsereteli, Murat Utkucu, Otari Varazanashvili, Mohammad Waseem, Hilal Yalçın and Mustafa Tolga Yılmaz.

## References

- Akkar S, Kale Ö, Ansari A, Durgaryan R et al (2014) EMME strong-motion database serving for predictive model selection to EMME ground-motion logic-tree applications. In: Second European conference on earthquake engineering and seismology, Istanbul, Turkey, abstract no. 3220
- Danciu L, Kale Ö, Akkar S (2016) The 2014 Earthquake Model of the Middle East: ground motion model and uncertainties. Bull Earthq Eng. <https://doi.org/10.1007/s10518-016-9989-1>
- Danciu L, Şeşetyan K, Demircioğlu MB, Gülen L, Zare M, Basili R, Elias A, Adamia S, Tsereteli M, Yalçın H, Utkucu M, Khan MA et al (2017) The 2014 Earthquake Model of the Middle East: seismogenic sources. Bull Earthq Eng. <https://doi.org/10.1007/s10518-017-0096-8>
- Gülen L, Şeşetyan K, Adamia S, Sadradze N, Gvencadze A, Karakhanyan A et al (2014) Earthquake Model of the Middle East (EMME) project: active faults and seismic sources second European conference on earthquake engineering and seismology, 2ECEES, 24–29 August 2014, Istanbul, Turkey, abstract no. 3216
- Şeşetyan K, Danciu L, Demircioğlu M, Giardini D, Erdik M, Akkar S, Gülen L, Zare M et al (2018) The 2014 Earthquake Model of the Middle East: overview and results. Bull Earthq Eng. <https://doi.org/10.1007/s10518-018-0346-4>
- Zare M, Amini H, Yazdi P, Sesetyan K, Demircioğlu MB, Kalafat D, Erdik M, Giardini D, Khan MA, Tsereteli N (2014) Recent developments of the Middle East catalog. J Seismol 18:749–772. <https://doi.org/10.1007/s10950-014-9444-1>