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ORIGINAL RESEARCH PAPER

# Seismic hazard map of the Middle East

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**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

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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.

# 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.

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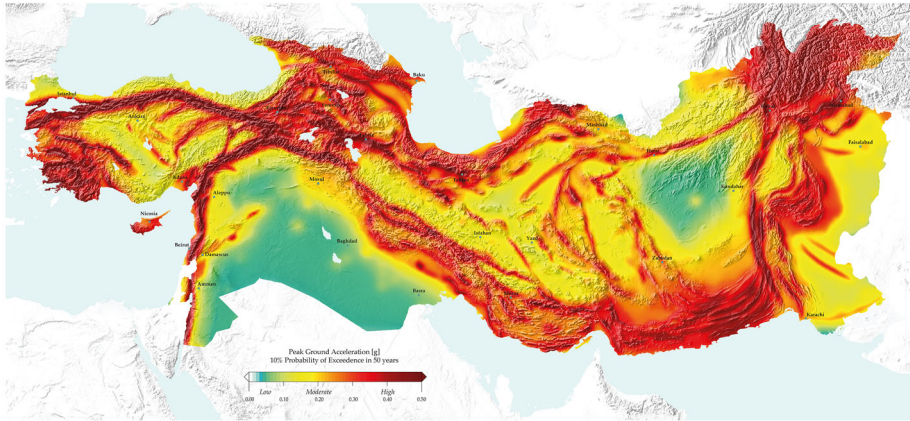[5]  Present Address: Department of Civil Engineering, Gebze Technical University, Kocaeli, Turkey

**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 Vs30 = 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 (PGA ≤ 10% of the gravitational acceleration [g]), yellow to orange colors moderate hazard (10%g < PGA ≤ 30%g) and red to brown colors identify high hazard areas (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).

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.

**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)

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