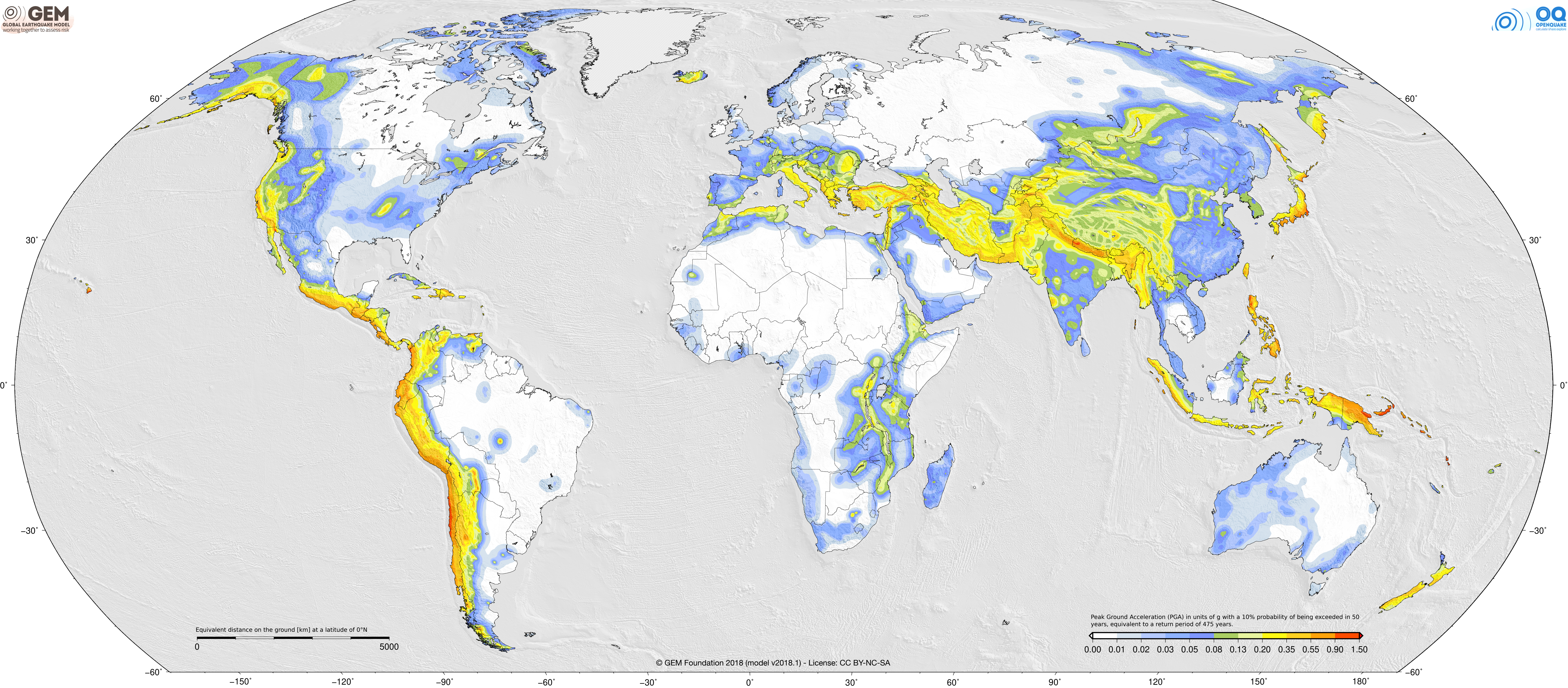


Global Earthquake Model



Global Seismic Hazard Map



Global Earthquake Model (GEM) Global Seismic Hazard Map

The Global Earthquake Model (GEM) Global Seismic Hazard Map (version 2018.1) depicts the geographic distribution of the Peak Ground Acceleration (PGA) with a 10% probability of being exceeded in 50 years, computed for reference rock conditions (shear wave velocity,  $V_{s0}$ , of 700-800 m/s). The map was created by collating maps computed using national and regional probabilistic seismic hazard models developed by various institutions and projects, and by GEM Foundation scientists. The OpenQuake engine, an open-source seismic hazard and risk calculation software developed principally by the GEM Foundation, was used to calculate the hazard values. A smoothing methodology was applied to homogenise hazard values along the model borders. The map is based on a database of hazard models described using the OpenQuake engine data format (NRMML); those models originally implemented in other software formats were converted into NRMML. While translating these models, various checks were performed to test the compatibility between the original results and the new results computed using the OpenQuake engine. Overall the differences between the original and translated model results are small, notwithstanding some diversity in modelling methodologies implemented in different hazard modelling software. The hashed areas in the map (e.g. Greenland) are currently not covered by a hazard model. The map and the underlying database of models are a dynamic framework, capable to incorporate newly released open models. Due to possible model limitations, regions portrayed with low hazard may still experience potentially damaging earthquakes. The GEM Foundation plans to release future updates of this map on a regular basis as new information becomes available. Technical details on the compilation of the hazard and risk maps and the underlying models are available at <http://www.globalquakemodel.org/gem>

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**Contacts:**  
GEM (Global Earthquake Model) Foundation  
Via Ferrata, 1 - 27100, Pavia, Italy  
[info@globalquakemodel.org](mailto:info@globalquakemodel.org)

More information available at:  
<http://www.globalquakemodel.org/gem>

Sponsors and major contributors



Contributing models

- Alaska, USA (ALS) - 2007**  
Developed by the United States Geological Survey and converted into the OpenQuake engine by GEM.  
• Authors: R.L. Weaver, O.S. Boyd, C.S. Mueller, C.G. Bufe, A.D. Frankel, M.D. Petersen  
• Website: <https://earthquake.usgs.gov/hazards/hazmaps/>
- Arabian Peninsula (APR) - 2016**  
Developed by the Saudi Geological Survey and converted into the OpenQuake engine by GEM.  
• Authors: H. Zaman, V. Selwyn, S. El-Hadi, Youssef, W. W. Alwadai, M. J. P. Rood, L. C. F. Stewart, M. El-Hadi  
• Website: <https://www.usgs.gov/science/volcanic-hazard/pages/new-asps>
- Australia (AUS) - 2016**  
Developed by Geoscience Australia.  
• Authors: T. Allen, J. Griffith, M. Leonard, D. Clark, H. Ghasseri  
• Website: <http://www.ga.gov.au/about/projects/safety/msha>
- Canada (CAN) - 2015**  
Developed by Natural Resources Canada, partly adapted into the OpenQuake engine by GEM.  
• Authors: J. Adams, S. Hachuk, T. Allen, G. Rogers  
• Website: <http://www.nrcc.gc.ca>
- Caribbean and Central America (CCA) - 2016**  
Developed within the project CCAHA, Cuba and Puerto Rico were included a posteriori by GEM. Organisations involved in CCAHA: GEM - University of Costa Rica, Costa Rica - Costa Rican Institute of Electricity, Costa Rica - Nicaraguan Institute of Territorial Studies, Nicaragua - Catholic University of El Salvador, El Salvador - Ministry of Environment and Natural Resources, El Salvador - Panama University, Panama.  
• Authors: J. Garcia-Pelaez, R. Gee, R. Styrón, V. Poggi
- Central Asia (CEA) - 2016**  
Developed within the EMCA project, coordinated by the Helmholtz German Research Centre for Geosciences, Germany. Organisations involved: Helmholtz Centre Potsdam, German Research Centre for Geosciences, Germany - The Republic of Tajikistan - Institute of Geophysical Research, Kazakhstan - International University of Innovation Technologies, Kyrgyzstan - Kyrgyzstan Institute of Seismology, Kyrgyzstan - Central Asian Institute of Applied Geosciences, Kyrgyzstan - Institute of Mechanics and Seismic Stability of Structures of the Academy of Sciences of Uzbekistan, Uzbekistan - Maykenov Institute of Seismology, Uzbekistan.  
• Authors: S. Ullah, D. Bindi, M. Pili, L. Danoli, G.A. Weatherill, E. Zuccollo, A. Ischuk, N.N. Mikhailova, K. Abdalrhmanov, S. Porcari, K. Fleming  
• Website: <http://www.emca-gem.org/>
- China (CHN) - 2015**  
Developed by the Institute of Geophysics of the China Earthquake Administration and converted into the OpenQuake engine by Changling Li within a collaboration between the Institute of Geophysics of the China Earthquake Administration, the Swiss Seismological Service, Swiss Federal Institute of Technology, Switzerland and GEM.  
• Authors: M. Gao, G. Chen, F. Xie, X. Xu, X. Li, Y. Yu  
• Website: <http://www.ces-igg.ac.cn/>
- Europe (EUR) - 2013**  
Developed within the EU-funded SHARE project, coordinated by the Swiss Federal Institute of Technology, Zurich, Switzerland. Organisations involved: Helmholtz Centre Potsdam, German Research Centre for Geosciences, Germany - The National Institute of Geophysics and Volcanology, Italy - Joseph Fourier University, France - University of Pavia, Italy - Aristotle University of Thessaloniki, Greece - The French Geological Survey, France - Center of Research in Astronomy, Astrophysics, and Geophysics, Algeria - Instituto Superior Tecnico, Portugal - Bogazici University, Turkey - National Laboratory for Civil Engineering, Portugal - Middle East Technical University, Turkey - Montenegro Seismological Observations, Montenegro - National Environment Research Council, United Kingdom - National Institute for Earth Physics, Romania - National and Kapodistrian University of Athens, Greece - Norwegian Seismic Array, Norway - Royal Observatory of Belgium, Belgium. Updated version of the model to be released in 2020.  
• Authors: J. Woessner, L. Danoli, D. Giardini, H. Crowley, F. Cotton, G. Grünthal, G. Valensise, R. Arvidsson, R. Bassi, M. Bello-Demicheli, S. Herrero, C. Meislin, R. W. Musson, A.N. Rovida, K. Sesayyan, M. Stucchi  
• Website: <http://www.share-eu.org/>
- Hawaii, USA (HAW) - 1998**  
Developed by the United States Geological Survey and converted into the OpenQuake engine by GEM.  
• Authors: F.W. Klein, A.D. Frankel, C.S. Mueller, R.L. Weaver, P.D. Okubo  
• Website: <https://earthquake.usgs.gov/hazards/hazmaps/>
- Indonesia (IDN) - 2017**  
Developed by the Team for Updating Seismic Hazard Maps of Indonesia. The team belongs to the National Center for Earthquake Studies under the Center for Research and Development of Housing and Settlements of the Ministry of Public Works and People Housing, Ministries involved: Ministry of Public Works and People Housing, Ministry of Energy and Mineral Resources, Ministry of Transportation, Ministry of Research, Technology and Higher Education, and National Disaster Management Authority of Indonesia. Organisations involved: Bureau of Meteorology, Climatology and Geophysics, Indonesian Research Institute, Geospatial Information Agency, Center for Research and Development of Housing and Settlements, Centre of Volcanology and Geological Hazard Mitigation, Indonesian Academy of Sciences, Bandung Institute of Technology, University of Indonesia, University of Gajah Mada, University of Diponegoro, Indonesian Society for Geotechnical Engineering, and Indonesian Disaster Expert Association. The team collaborated internationally with Geoscience Australia, Australia.  
• Authors: M. Inayati, L. Fauzi, D. Natakawidjaja, I. Maliano, S. Widayanto, W. Triyoso, A. Rudiyanto, S. Hidayati, M. Asuriani, M. Ridwan, P. Cummins
- India and surroundings (IND) - 2012**  
Developed by Nath and Thirugobalan (2012), revised and implemented into the OpenQuake engine by N. Ackenley, Natural Resources Canada.  
• Authors: N. Ackenley, K.K.S. Thirugobalan, S.K. Nath
- Japan (JPN) - 2014**  
Developed by the Headquarters for Earthquake Research Promotion, Japan and converted into the OpenQuake engine format within a collaboration between the National Research Institute for Earth Science and Disaster Resilience, Japan, and GEM.  
• Authors: H. Fujiwara, N. Morikawa, S. Kawai, S. Aoi, S. Senna, T. Maeda, H. Aoi, K. X. Han, A. Iwaki, K. Wakamitsu, M. Imoto, N. Hasegawa, T. Okumura, T. Hayakawa, M. Takahashi  
• Website: <http://www.jishin.go.jp/>
- Korean Peninsula (KOR) - 2018**  
Assembled by GEM.
- Mexico (MEX) - 2016**  
Developed by GEM.  
• Authors: J. Garcia-Pelaez, R. Gee, R. Styrón
- Middle East (ME) - 2016**  
Developed within the EMME project, jointly coordinated by the Swiss Federal Institute of Technology, Switzerland, and the Kandilli Observatory and Earthquake Research Institute, Turkey. Institutions involved: International Institute for Earthquake Engineering and Seismology, Iran, Middle East Technical University, Turkey, Sakarya University, Turkey, University of Peshawar, Pakistan, Yarmouk University, Jordan, American University of Beirut, Lebanon, Iwate Jikei University, Japan, Georgia National Academy of Sciences, Armenia, National Academy of Sciences, Azerbaijan.  
• Authors: D. Giardini, L. Danoli, M. Erdik, K. Sesayyan, M.B. Demircioglu, S. Akkar, L. Gulik, M. Zare, S. Adami, A. Ansari, A. Asakayan, A. Askan, M. Awanoglu, H. Babacan, T. Chelidze, R. Durgunyan, A. Eliaz, H. Hamehlo, K. Hessami, D. Kalkan, O. Kalkan, A. Karakhanian, M.A. Khan, T. Mamadi, M. Al-Qaroufi, M. Sayab, N. Tavakoli, M. Utku, O. Wazwanian, M. Wazwanian, H. Yagci, M.T. Yilmaz  
• Website: <http://www.earth.org/>
- Northern Africa (NAF) - 2016**  
Developed by GEM.  
• Authors: V. Poggi, J. Garcia-Pelaez, R. Styrón
- Northeast Asia (NEA) - 2016**  
Developed by GEM.  
• Authors: V. Poggi, J. Garcia-Pelaez, R. Styrón
- Northwestern Asia (NWA) - 2016**  
Developed by GEM and the Swiss Federal Institute of Technology, Switzerland.  
• Authors: V. Poggi, L. Danoli
- New Zealand (NZL) - 2010 corrected**  
GNS Science led the development of the model and converted it into the OpenQuake engine.  
• Authors: E.R. Abbott, N. Horspool, M. Gerstenberger, R. Huo, C. Van Houtte, G. McVerry, S. Canessa  
• Authors (2015 model): M. Shilling, G. McVerry, M. Gerstenberger, N. Litchfield, R. Van Dessen, K. Berryman, P. Barnes, L. Wallace, P. Villamor, R. Langridge, G. Lamarche, S. Nodder, M. Reynolds, B. Bradley, D. Rhoades, W. Smith, A. Nicol, J. Pelling, K. Clark, K. Jaccott  
• Website: <https://www.gns.govt.nz/>
- Pacific Islands (PAC) - 2016**  
Developed by GEM.  
• Authors: K. Johnson
- Philippines (PHL) - 2016**  
Developed jointly by the Philippine Institute of Volcanology and Seismology and GEM.  
• Authors: PHIVOLCS, K. Johnson, R. Styrón  
• Website: <https://www.phivolcs.dost.gov.ph/>
- Papua New Guinea (PNG) - 2015**  
Developed with a collaboration between the Port Moresby Geophysical Observatory and Geoscience Australia.  
• Authors: H. Ghasseri, C. McKee, M. Leonard, P. Cummins, M. Mohai, S. Spiliopoulos, F. Tarazu, E. Buri
- South America (SAM) - 2016**  
Initially developed within the SARA project and updated by GEM. Organisations involved: GEM, Colombian Geological Survey, Colombia - National University of Colombia, Colombia - University of Valle, Colombia - Venezuelan Foundation for Seismological Research, Venezuela - University of Merida, Venezuela - National Observatory, Brazil - Institute of Astronomy, Geophysics and Atmospheric Sciences, Brazil - Federal University of Rio Grande do Norte, Brazil - National Polytechnic University, Ecuador - San Carlos Observatory - Bolivia - University of Chile, Chile - University of Concepcion, Chile - Pontificia Universidad Católica de Chile, Chile - Research Center for Disaster Risk Management, Chile - Peruvian Geological Service, Peru - University of San Luis, Argentina - University of Antofagasta, Argentina - National Institute of Seismic Prevention, Argentina - National Institute of Geophysics and Volcanology, Italy  
• Authors: J. Garcia-Pelaez, M. Pagani, K. Johnson, R. Styrón, V. Poggi
- Southwestern Asia (SEA) - 2016**  
Developed by the United States Geological Survey, Singapore and Mahidol University, Thailand.  
• Authors: C.-H. Chan, T. Donthammarath  
• Website: <http://the-earth-engine.org/tetm/index.php>
- Sub-Saharan Africa (SSA) - 2016**  
Developed by GEM in collaboration with AfricaArray within the project SSAHARA.  
• Authors: V. Poggi, R. Durrheim, G.M. Talska, G.A. Weatherill, R. Gee, M. Pagani, A. Nyahkide, D. Delvaux
- Taiwan (TWM) - 2015**  
Developed within the Taiwan Earthquake Model initiative, a collaboration between various Taiwanese research institutions.  
• Authors: Y.-J. Wang, C.-H. Chan, Y.-T. Lee, K.-F. Ma, J.-H. Shyu, R.-J. Rau, C.-T. Cheng  
• Website: <http://the-earth-engine.org/tetm/index.php>
- California, USA (UCF) - 2014**  
Developed within a project supported by the United States Geological Survey, the Southern California Earthquake Center, the California Geological Survey and the California Earthquake Authority. The model was converted into the OpenQuake engine by GEM.  
• Authors: H. Field, J.P. Blais, P. Bile, T.E. Dawson, K.R. Felzer, D.D. Jackson, K.M. Johnson, T.H. Jordan, C. Madden, A.J. Michael, K.R. Milnes, M.T. Page, J. Parsons, P.M. Powers, B.E. Shaw, W.R. Thatcher, R.J. Walden, Y. Zeng  
• Website: <http://webop.org/ucf03/>
- United States of America (USA) - 2014**  
Developed by the United States Geological Survey and converted into the OpenQuake engine by GEM.  
• Authors: M.D. Petersen, M.P. Moschetti, P.M. Powers, C.S. Mueller, K. M. Haller, A.D. Frankel, Y. Zeng, S. Rezaiean, S.C. Hammer, O.S. Boyd, E.H. Field, R. Chen, K.S. Rukstales, N. Luco, R.L. Wheeler, R.A. Williams, A.J. Olsen  
• Website: <https://earthquake.usgs.gov/hazards/hazmaps/>
- Western Africa (WAF) - 2016**  
Developed by GEM.  
• Authors: V. Poggi
- South Africa (ZAF) - 2016**  
Developed by the Council of Geoscience, South Africa.  
• Authors: V. Maki, B. Marzocchi, T. Molenaar, B.S. Zulu, T. Pule, S. Myerhoff, G. W. Rathod  
• Website: <http://www.geoscience.org.za>

For models developed by GEM, see <https://www.globalquakemodel.org/gem/>

Global Earthquake Model (GEM) Foundation

The GEM Global Seismic Hazard Map is a product of the GEM Foundation. Initiated by the OECD's Global Science Forum in 2006, GEM was formed in 2009 as a non-profit foundation in Pavia, Italy, funded through a public-private sponsorship with the vision to create a world that is resilient to earthquakes. Participants represent national research, applied science or disaster management institutions, the private sector and international organisations. GEM continues the tradition of the Global Seismic Hazard Assessment Program (GSHAP), which produced the first global seismic hazard map arising from a global collaborative effort of scientists in 1999 in support of the UN International Decade of Natural Disaster Reduction (IDNDR). GEM's collaborative network comprises more than 70 public and private institutions organised under more than 25 regional, national and multilateral projects. Observing its core values of collaboration, transparency, openness, credibility and serving the public good, the GEM initiative extends the scope of work of GSHAP to the risk domain, providing an institutional framework for continuous updates and fostering direct applications to risk reduction and prevention projects. GEM's OpenQuake platform ([platform.openquake.org](http://platform.openquake.org)) provides access to data, models, tools and software behind the maps. GEM's open-source OpenQuake engine enables probabilistic hazard and risk calculations worldwide and at all scales, from global down to regional, national, local, and site-specific in a single software package. The Sendai Framework for Disaster Risk Reduction (SFDRR) calls for "decision-making on disaster risk reduction to be based on solid and openly accessible scientific work". GEM supports the SFDRR goals by contributing openly accessible products for hazard and risk assessment and capacity development for risk reduction projects. GEM also serves as a baseline or exemplar for the development of a broader multi-hazard framework for risk assessment in support of a holistic and comprehensive approach to disaster risk reduction.

Legal statements

This map was created for dissemination purposes. The information included in this map must not be used for the design of earthquake-resistant structures or to support any important decision involving human life, capital and movable and immovable properties. The values of seismic hazard in this map do not constitute an alternative nor do they replace building actions defined in national building codes. Readers seeking this information should consult national databases. This hazard map is the combination of results computed using 30 hazard input models covering the vast majority of landmass. These models represent the best information publicly accessible, and the GEM Foundation recognises their credibility and authoritativeness. This hazard map results from an integration process that is solely the responsibility of the GEM Foundation.