PSHA input model documentation for Europe (EUR)

GEM Hazard Team

Version history

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

Version	2018.1	2019.1	2022.1	2023.1	Changelog
v2013.0.0	X				First version of the SHARE model.
v2013.1.0		X			Updated to include full coverage in Ukraine and Belarus with sources from the NWA model.
v2020.0.0			X		The hazard model for the Euro-Mediterranean region developed by EFHER
v2020.0.1				X	Mmin extended to M4 for crustal distributed seismicity. Source ids were revised to work with disaggregation by source. Sources from NWA were added as in v2013.1.0.
ESHM20_v1					As in v2020.1.0_aelo

The following text describes ESHM20_v1.

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1 Summary

The Global Hazard Mosaic uses the 2020 European Seismic Hazard Model (ESHM20) to cover the Euro-Mediterranean region. The ESHM20 model uses the same principles as the Seismic Hazard Harmonization in Europe (SHARE) Project model *(Woessner et al., 2015)*, with state-of-the art procedures homogeneously applied for the pan-European region. A fully probabilistic framework was adopted in the hazard model implementation, using input datasets that are harmonized across national borders.

ESHM20 was developed by the Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe (SERA) and funded by the European Union's Horizon 2020 research and innovation programme. For more details, refer to http://www.sera-eu.org/en/home/ and http://www.hazard.efehr.org/en/home/.

The model was originally implemented in the https://github.com/gem/oq-engine/. In addition to the conterminous pan-European region, this model was used to compute hazard for the Kaliningrad Region of Russia, Iceland, and the Canary Islands. Athough ESHM20 covers Turkey, the Global Hazard Mosaic currently uses the EMME model.

2 Tectonic overview

Seismic and tectonic activity in Europe is concentrated in the south, relating to the plate boundaries in the Mediterranean region. Convergence between Africa and Europe has produced a wide reverse fault and subduction zone complex stretching from the Rif-Betic Cordillera in southern Iberia and northern Morocco, east through the Algerian and Tunisian continental slopes and then through the southern Italian region (where subduction of microplates is quite complicated) and then through the Hellenic subduction zone south of the Aegean Islands. North and west of the Aegean, the North Anatolian Fault forms a strike-slip plate boundary with the Anatolian Plate and distributed faulting in the southern Balkan Peninsula. The Italian Peninsula is also faulted throughout, with active extension along normal faults cutting through the high Apennines and reverse faults in the Adriatic Sea. Farther north, some slow strain and seismicity are present throughout the Alpine chain from Spain through the Balkans. Additional very slow faulting extends through the northern Europe in zones such as the Rhine Graben. In the Carpathians, the subducted slab from a previous episode of plate convergence still produces moderate to large magnitude earthquakes as the slab deforms and sinks into the mantle; fortunately, these earthquakes may be quite deep and less damaging than if they were in the European crust.

3 Basic Datasets

- As part of the ESHM20, the European PreInstrumental earthquake CAtalogue *(EPICA)* was compiled, consisting of historical earthquakes occurring from 1000-1899; see *Rovida & Antonucci (2021)* and https://www.emidius.eu/epica/.
- The instrumental earthquake catalogue covers the period 1900 to the end of 2014 and builds on the previous European-Mediterranean Earthquake Catalogue (EMEC) from *Grünthal & Wahlström (2012)*.
- The European Database of Seismogenic Faults 2013 (*EDSF13; Basili et al., 2013*) was update to produce the European Fault-Source Model 2020 (EFSM20; *Basili et al., 2020*) by compiling fault data from numerous sources. The EFSM20 consists of two main categories of seismogenic faults - crustal faults and subduction zones - that are within a 300 km buffer around the region of model coverage. See *Danciu et al., 2021* for more information.
- For the ground motion characterisation, the pan-European Engineering Strong Motion (ESM) flatfile *(Lanzano et al., 2019)* was used to develop new GMMs to use in ESHM20, as well as to make adjustments to existing ones.

4 Hazard Model

4.1 Seismic Source Characterisation

The seismic source characterisation (SSC) is based on seismic source models of the relevant national models where possible, and is fully harmonized such that there is continuity across borders.

The SSC includes the following main components:

- an **area source** model, which is based on the ESHM13 area source model with updates based on more recent national models, accounting for shallow crustal seismicity as well as aspects of the other components
- active faults (**simple fault sources**) and background/off-fault seismicity (gridded **point sources** with smoothed rates) to cover shallow seismicity
- subduction interface (**complex fault sources**) and subduction intraslab (**area sources**) sources
- volcanic seismicity (**area sources**)
- deep, non-subduction seismicity (**area sources**)

The source model logic tree initially diverges into two main branches with equal weights. These two branches are focused on the shallow crustal seismicity, which are considered alternative SSMs.

- *Crustal Branch 1*: the area source model
- *Crustal Branch 2*: the active faults and background seismcity model

For the area source branch, as well as all other components of the source model that use area sources, a second branching level is applied that varies the method used to model the recurrence (the MFDs): the double-truncated Gutenberg-Richter (GR) (weight=0.6) and the tapered Pareto (weight=0.4) distributions. Additionally, epistemic uncertainty in the maximum magnitude and GR parameters (three branches each with unequal weighting) are considered for individual sources. In Crustal Branch 2, the epistemic uncertainties in fault slip rate and maximum magnitude are considered using three hyptoheses for each. The interface sources are characterized by a single model (based on the central model from an exploratory logic tree), and the smoothed seismicity is modeled without epistemic uncertainty.

4.2 Ground Motion Characterisation

The ground motion logic tree for ESHM20 considers a smaller number of core backbone ground motion models *(GMM)* to which a set of adjustments are applied. The epistemic uncertainties in ground motion are considered within these adjustments, and described herein; for a comprehensive explanation of the adjustments, refer to *Danciu et al., 2021* and the OpenQuake GSIM documentation (see the hyperlinks in Table **??**). In order to implement the backbone approach in the ESHM20 model, new GMMs were developed for some tectonic regions types, and adjustments made to existing GMMs for others; the full scaled backbone logic tree was constructed around these.

The ground motion logic tree of the ESHM20 model is quite complex and hence the representation below indicates only the core backbone GMM used for each of the different tectonic region types. The regional adjustments are applied to the listed GMM, using logic trees to account for five possible stress conditions (very low, low, mid, high, and very high) and three attenuation rates (fast, central and slow). This branching scheme is used for active shallow crust, craton, Iceland Atlantic active region, subduction interface, slab, and non-subduction deep regions. The volcanic region has only a single branch.

For more details, refer to *Danciu et al., 2021*.

Non-Subduction Deep	**Weight**
BCHydroESHM20SSlab	1.0
Volcanic	**Weight**
LanzanoLuzi2019shallow	1.0
Iceland Atlantic Active Region	**Weight**
KothaEtAl2020ESHM20	1.0
Craton	**Weight**
KothaEtAl2020ESHM20	0.2
ESHM20Craton	0.8
Subduction Inslab	**Weight**
BCHydroESHM20SSlab	1.0
Subduction Interface	**Weight**
BCHydroESHM20SInter	1.0

Shallow Default	**Weight**
KothaEtAl2020ESHM20	1.0

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

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: Bratislava, Sofia, Torshavn, Belgrade, Stockholm, Ljubljana, Gibraltar, Dublin, Andorra La Valla, Minsk, Rome, Riga, Bern, Vienna, Reykjavik, Valletta, Warsaw, Prague, Chisinau, London, Vaduz, Amsterdam, Nieuw Amsterdam, Budapest, Ankara, Berlin, Monaco, San Marino, Tirana, St. Peter Port, Tallinn, Brussels, Sarajevo, Oslo, Vilnius, Podgorica, Lisbon, Copenhagen, Kyiv, Athens, Helsinki, Skopje, Zagreb, Paris, Madrid, Nicosia, Bucharest and Luxembourg. 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

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Last processed: **Friday 30th June, 2023 @ 10:17**

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