Fact Sheet:
The 2020 European Seismic Hazard Model

Key facts

- The European Seismic Hazard Model 2020 (hereinafter ESHM20), following the 2013 and the 2002 models, is the most recent updated version of the earthquake hazard model for the Euro-Mediterranean region.
- Turkey, Greece, Albania, Italy, and Romania are the regions with the highest hazard, followed by Iceland, Bulgaria, Croatia and Bosnia-Herzegovina.
- Regions of relatively moderate ground shaking hazard are, i.e. Rhine Graben in Germany, France, Switzerland and Belgium, the Valleys and Alpine front in Switzerland, Pyrenees Mountains in France and Spain, Southern Spain, Lisbon area, Azores Islands, and Southern Portugal.
- Two ground shaking maps at 475 years return period are derived from the ESHM20 model and included in Annex A of EN 1998-1-1:2021, which will now undergo the enquiry and formal voting procedure by CEN member countries.
- Model calculation was done with the OpenQuake open-source software and ESHM20 will replace the ESHM13 with the Global Earthquake Mosaic (Pagani et al., 2021).
- ESHM20 is a key component of the first open-access European Seismic Risk Model (ESRM20; Crowley et al., 2021).

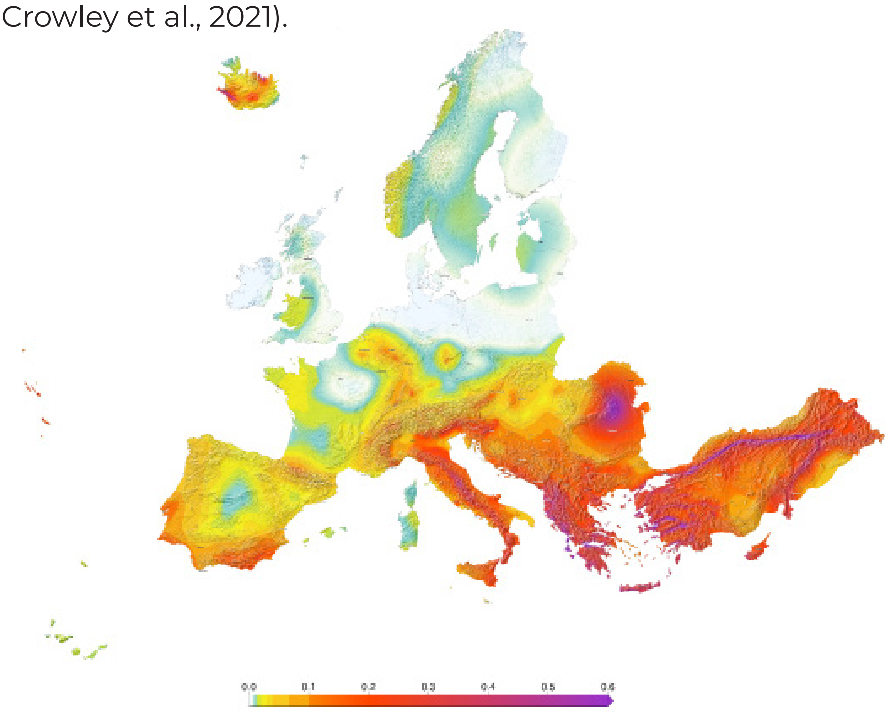

Fig. 1 Spatial distribution of ground shaking levels with an equal exceedance probability (10 %) in 50 years. Ground shaking is described by peak ground acceleration (PGA) in units of gravity (g). Cold colours indicate comparatively low hazard areas (PGA≤ 0.1 g), yellow and orange indicate moderate hazard values (0.1 g<PGA ≤ 0.25 g), and red colours indicate high hazard areas (PGA≥ 0.25 g).

An updated seismic hazard model for Europe

Overview

An open and collaborative framework was adopted for the development of the 2020 update of the European seismic hazard assessment. The work was coordinated and conducted by a core team (Danciu et al., 2021), with contributions from a large community of earth scientists, seismologists, geologists, earthquake engineers, statisticians, software developers and outreach specialists.

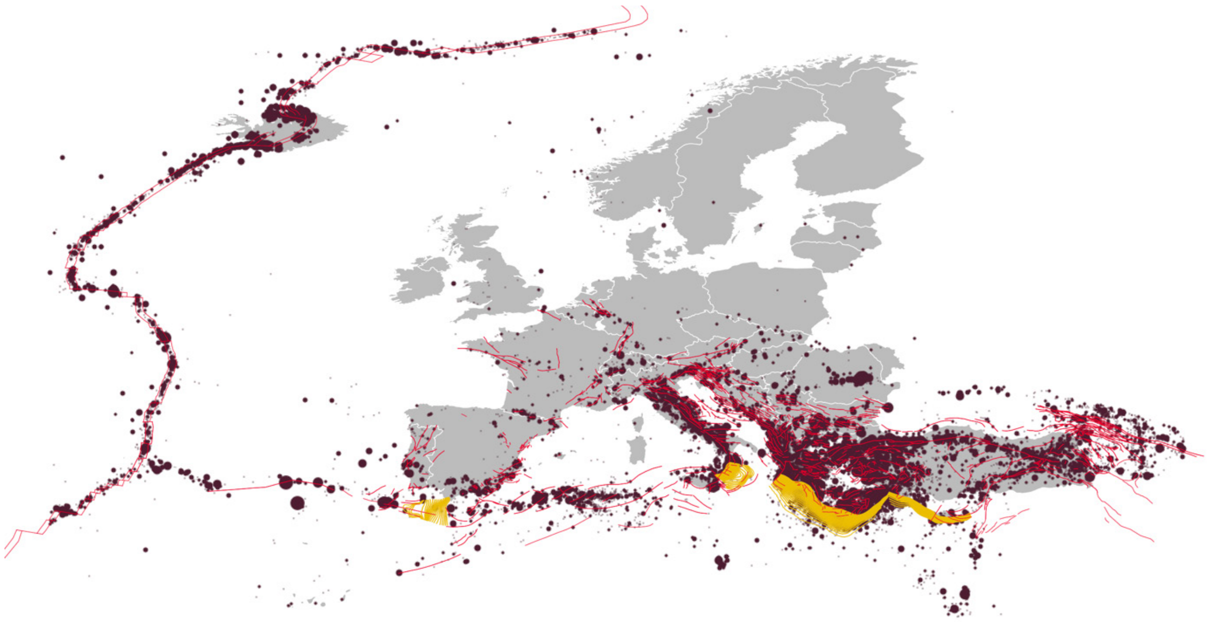

Fig. 2 Unified earthquake catalogue (black dots) together with the active faults (red lines) and subduction interface zones.

A unified earthquake catalogue was compiled without country borders constraints, combining the revised historical (Rovida & Antonucci, 2021a) and updated instrumental earthquake (Grünthal & Wahlström, 2012) information. The updated earthquake catalogue of ESHM20 contains revised earthquake parameters and new entries when compared with the 2013 version of the earthquake catalogue. Overall, the number of catalogue entries has doubled, mainly due to additional eight years of data. Worth noticing that the resulting number of moment magnitude Mw ≥ 5 events increased by 1980 events, and 466 out of them occurred after 31-12-2006. The unified earthquake catalogue contains shallow depth earthquakes, volcanic, deep and subduction seismicity is illustrated in Fig. 1. Novel data-driven techniques have been used to analyse the unified earthquake catalogue statistically. Statistical tests and sensitivity analyses were used to assess the completeness and the declustering of the unified catalogue (Danciu et al., 2021).

The update of the active faults' dataset includes primarily the local compilations that covered a region of about 300 km around all Europe, and two main categories of seismogenic faults are considered, i.e. crustal faults and subduction zones. The starting point to build the new fault model is the original database EDSF13 (Basili et al., 2013; Giardini et al., 2013). The largest regions that remained unmodified are in the Balkans and northern Africa. According to individual studies, most regions were either entirely replaced by new datasets or partly revised. Additions in regions that EDSF13 did not cover are in Iceland, France, and the northern Mid-Atlantic plate boundary. About 1,200 active fault sources were mapped and fully characterised to include information about the fault geometry (i.e. location: Lat, Lon, Depth; size: Length, Width; orientation: Strike, Dip and behaviour Rake and Slip Rate).

Subduction zones are complex systems where different types of potential earthquake sources exist. We rely on the assumption that the earthquakes occurring in the upper plate of subduction zones are dealt with by the crustal fault model. We updated the subduction zones of EDSF13, which covered the Mediterranean subduction systems, which include the Calabrian Arc, the Hellenic Arc, and the Cyprus Arc. In addition to searching the literature for more updated data, we conducted original work to reconstruct the subduction system of the Gibraltar Arc. The geometry of the Hellenic Arc and Cyprus Arc slabs was recently revisited in the framework of a tsunami hazard project (Basili et al., 2021) and re-examined in light of the SLAB 2 model (Hayes et al., 2018).

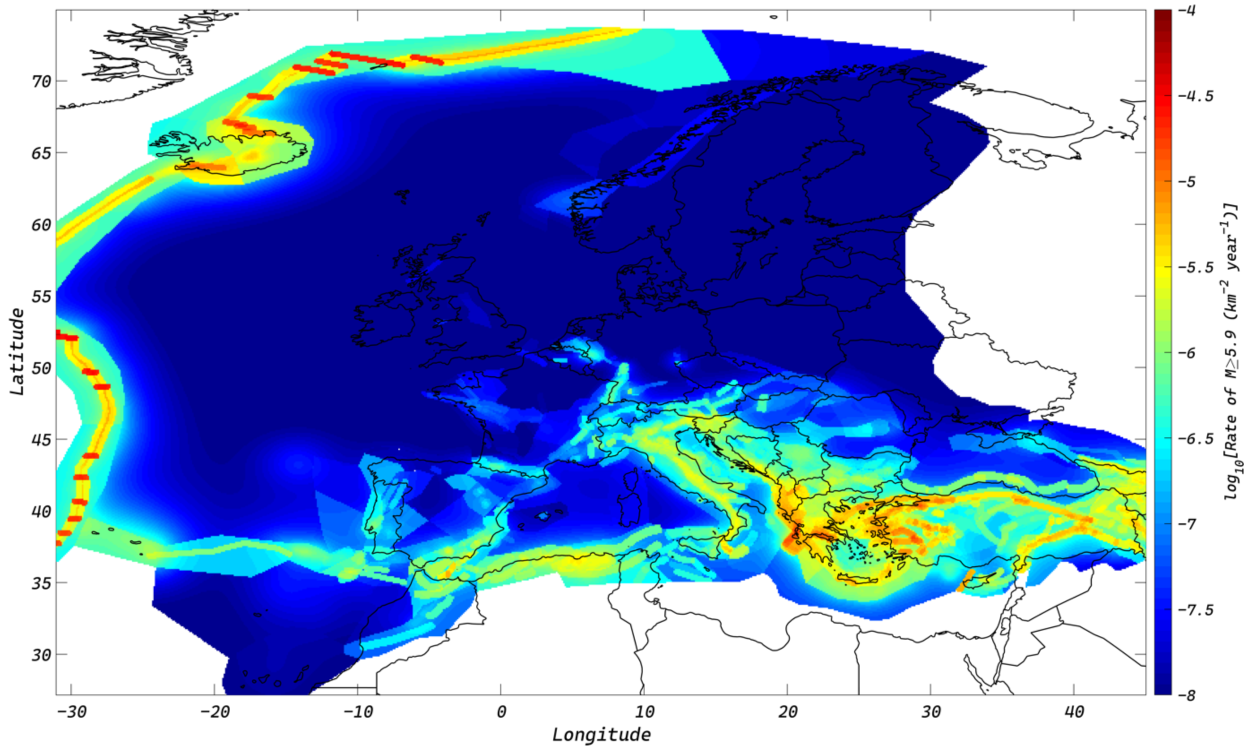

Fig. 2 Spatial distribution of the cumulative earthquake rates for Mw>5.9 normalised per units of area (km²) and time (per year).

A state-of-the-art seismogenic source model consisting of a fully cross border harmonised area source model, a background seismicity and an active faults model. Subduction interface and deep seismicity have been modelled as well to capture the spatial and temporal patterns of seismicity across the Euro-Mediterranean region. The time-independent earthquake rates forecast for earthquakes with magnitude Mw > 5.9 of the ensemble models is illustrated in Fig. 2.

A new ground motion characteristic model, based on the most recent ground motion recordings and state-of-the-art backbone modelling to capture the inherent epistemic uncertainties. The development of the ground motion model (GMM) logic tree for a region should aim to leverage as far as possible on the available strong motion data in order to characterise the expected ground motion from earthquakes, its aleatory variability, its epistemic uncertainty and its variability from region to region. In the ESHM20, we adopt a novel approach for characterising epistemic uncertainty, which is built around the concept of a scaled backbone ground motion model logic tree. In this approach, a single ground motion model is calibrated (or selected from the literature), and to this model, adjustment factors are applied that quantify the uncertainty in the expected ground motion as a result of the limited knowledge on the seismological properties in a region.

We not only quantify epistemic uncertainty in terms of a parametrised statistical distribution, but we also set in place a framework through which new information and/or information at a regional scale can adapt the backbone GMM logic tree and reduce the epistemic uncertainty over time. The newly proposed scaled backbone ground motion model logic tree applies to the three main seismotectonic region types in Europe: shallow crustal seismicity (non-craton), seismicity in the stable craton region of north-eastern Europe, and subduction and deep seismicity (including the Hellenic, Calabrian, Cypriot and Gibraltar arcs, as well as the Vrancea deep seismic zone). A more comprehensive discussion of the theoretical and practical aspects of the ESHM20 GMM logic tree can be found in Kotha et al., 2020, 2022; Weatherill et al., 2020; Weatherill & Cotton, 2020, and Danciu et al., 2021.

Computation of the seismic hazard for a large-scale region covering the entire Euro-Mediterranean region was done with OpenQuake-engine v13.3 (Pagani et al., 2014).

Results

The key outcomes are the probabilistic estimates of the ground shaking across the Euro-Mediterranean region and Turkey to support the update of the next generation of the Earthquake Resistance Design Standard (Eurocode 8) of CEN/TC250/SC8. As such, for more than 120,000 grid points across Europe, the model outcome includes the weighted mean, median (50^{th}) and four quantiles (5^{th}, 16^{th}, 84^{th} and 95^{th}) for various intensity measure types: peak ground acceleration (PGA) and response spectra acceleration with 5% damping at predominant periods in the range of 0.05 s to 8 s.

The reference site conditions are Vs, 30 ≥ 800 m/s. The main results are:

- Hazard maps for specified intensity measure types and five mean return periods (i.e. 50, 475, 975, 2500 and 5000 years)
- Hazard curves at every computational site, depicting the mean, median (50^{th}) and four quantiles (5^{th}, 16^{th}, 84^{th} and 95^{th}) for all intensity measure types
- Uniform Hazard Spectra at every computational site, depicting the mean, median (50th) and four quantiles (5^{th}, 16^{th}, 84^{th} and 95^{th}) and five mean return periods (i.e. 50, 475, 975, 2,500 and 5,000 years)

Important notes

The ESHM20 results constitute an updated reference for the European region and Turkey, but these results do not replace nor modify the existing national design regulations and seismic provisions. Furthermore, in Europe, ground motion hazard estimates do not directly translate into design values; these must be conformed for seismic design and construction of buildings at the national level provided by the national design codes or by Nationally Determined Parameters (NDPs) in EN Eurocodes.

Comparison with ESHM13

Generally, the ESHM13 and ESHM20 maps have a similar spatial pattern, with overall lower values in most of the areas in the new hazard maps, as shown in Fig. 3, together with a map of the ESHM20-ESHM13 values differ at each site. The most considerable reduction between the two models is observed in Iceland due to the changes in the earthquake catalogues, active faults and calibrated ground motion models. However, increased values are also observed in some areas in Romania, Albania, Greece, Western Turkey, Southern Spain and Southern Portugal.

These differences are likely caused by the updated seismogenic sources and new backbone ground motion models. Changes in the seismogenic sources cause many local differences across the entire region. Regional discrepancies in the earthquake rates are likely caused by the new earthquake catalogue, new completeness time-magnitude intervals, new magnitude frequency distributions, updated slip rates and maximum magnitude of the faults, new adaptive-smoothing technique, new subduction sources, new logic tree and its implementation.

Furthermore, Weatherill et al. (2020) discuss the comparison between the two ground motion models and discusses the impact of the updated ground motion data on the new models used for ESHM20.

For further information, please refer to Danciu et al., 2021.

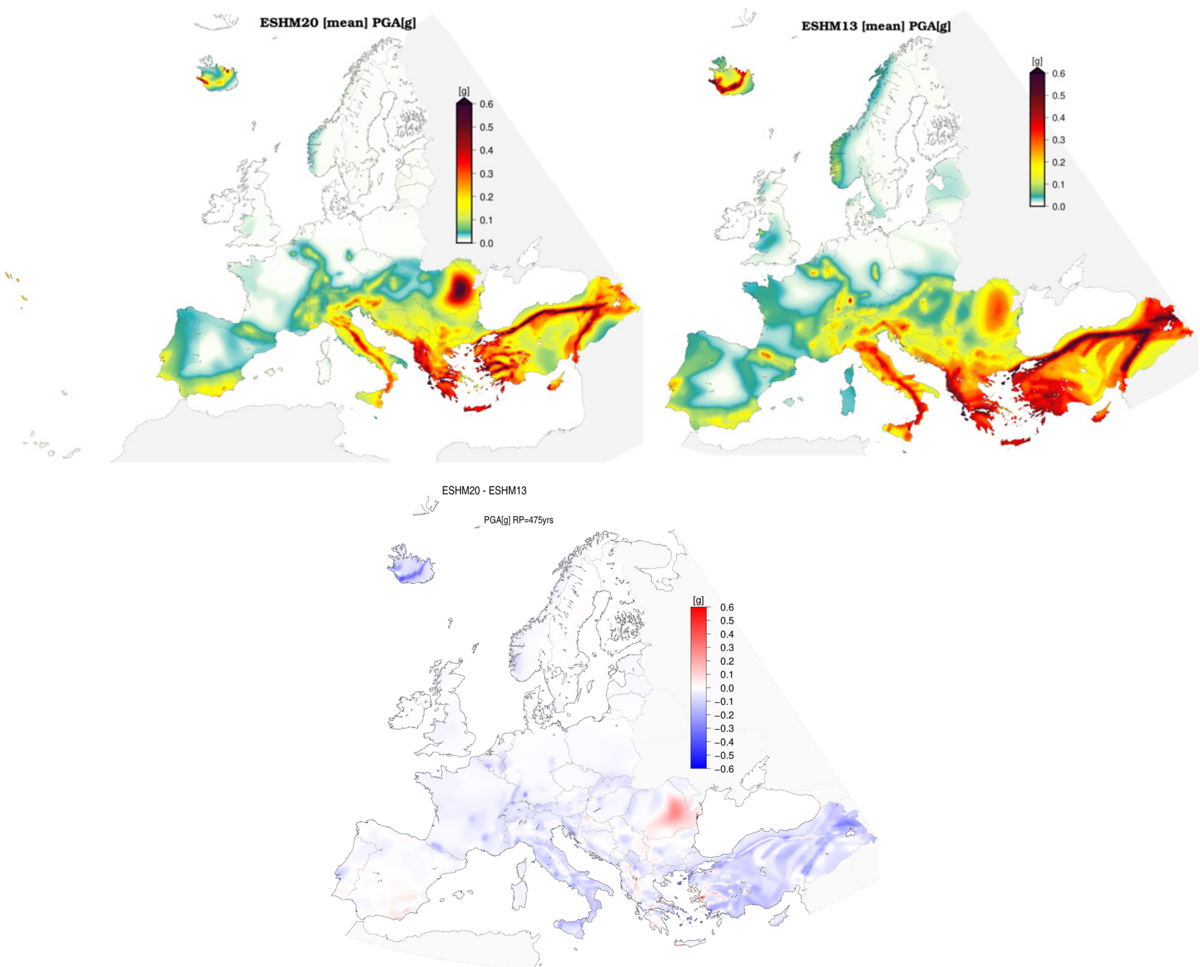

Fig. 3 Spatial variability of the PGA [g] difference on mean values of the ESHM20 versus ESHM13 for a return period of 475yrs. Red colour indicates an increase of PGA values when compared with the ESHM13 estimates, and the blue colour indicates the opposite. The 475yrs – PGA [g] hazard maps for ESHM20 (top left) and for ESHM13 (top right) are also illustrated.

More information

Are you interested in additional explanatory material? On www.efehr.org, you will find videos, brochures, access to technical reports, maps and much more information about earthquake hazard and risk across Europe.

Data access

More information, specific data, and parameters are available on www.hazard.efehr.org. The input files of the model have been released on the EFEHR GitLab repository for reproducibility of the results and to allow users to further explore the seismic hazard model: https://gitlab.seismo.ethz.ch/efehr/eshm20.

The scientific data and products of the 2020 European Seismic Hazard Model are openly released under the Creative Commons Attribution 4.0 license (CC BY 4.0). These products can therefore be used for private, scientific, commercial and non-commercial purposes, provided adequate citation is used.

Documentation

A technical report on the model is available for download at this site:
www.hazard.efehr.org/en/Documentation/specific-hazard-models/europe/eshm2020-overview/.

Maps

A selection of precomputed results from the hazard model are directly accessible through maps and web services at the following link: www.hazard.efehr.org.

Citation

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Contributors

A core team of researchers from different institutions across Europe worked collaboratively in the framework of various projects to develop the 2020 European Seismic Hazard Model (ESHM20). Many more have contributed to the development of ESHM20 by different means including data compilation and curation, knowledge exchange or by providing feedback at meetings and webinars. This has all been undertaken in close collaboration with the GEM Foundation and the European Plate Observing System (EPOS).

→ A list with all names and institutions that have contributed can be found at www.hazard.efehr.org.

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