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DELIVERABLE

D25.6 ESHM20: documentation, data and models for EFEHR distribution

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Summary – Note to the Project Management and EC officer

This deliverable summarizes the status of the datasets, documentation and web access of the ESHM20.

Following the workshop that took place in EUCENTRE (Pavia, Italy) on Monday 14th October 2019, an agreement on the products that SERA JRA3 would produce for CEN/TC250/SC8 was made and documented in Deliverable D2.14 (Stakeholders workshop M30). In this meeting, it was agreed the roadmap to deliver the ESHM20, with an agreement of the official release of the ESHM20 in Autumn 2020. As an intermediate phase, a beta model (pre-release) will be computed at the end of SERA Project (April 2020). This model will be revised by the national representatives well as the SC8 technical committee in the next three months. Within the review process it shall be expected that the model will evolve until mid 2020, thus the current documentation will be augmented with the review feedback and/or recommendations. Note, that the web-link provided in this report are subject to change as the new datasets and products are finalized. An accompanying report and a scientific (peer-reviewed) paper describing the final model in detail is planned beyond the end of the SERA Project (April 2020). Thus, in the remaining reporting period, this deliverable will be further updated to describe the final model, datasets and hazard products.

All datasets, inputs, derived models and hazard results will be made available, open-access through the web-portal of European Facilities of the Earthquake Hazard and Risk (www.efehr.org).

1 ESHM20 Data Access: the web-platform of the European Facilities of Seismic Hazard and Risk (www.efehr.org)

The European Facilities for Earthquake Hazard and Risk web-portal (hereinafter, EFEHR) was designed as a sustainable community resources and services for European Earthquake Hazard and Risk Consortium (established in October 2019, further details at www.efehr.org/governance).

The EFEHR web-platform facilitates global, open-access to online data, interactive products and services relevant for seismic hazard and risk in Europe. EFEHR-portal collects and fully displays the earthquake-related models and tools as originated from EU FP7 research projects: SHARE (2010- 2013), NERA (2010-2014) and SYNER-G (2009-2012). The EFEHR infrastructure consists of databases, web-services and display technologies hosted by ETH Zurich, and is one of the core services of EPOS Seismology(https://www.epos-ip.org/data-services/community-services-tcs/seismology). The EFEHR web-portal have been actively developed within the SERA WP21 - VA4 and details of the main architecture, web services and status of the database are reported in the deliverable SERA D18.1 to D18.4 and not repeated here.

The portal consists of web-services linking to the main hazard outputs (i.e. seismic hazard maps, seismic hazard curves and uniform hazard spectra). The 2020 European Seismic Hazard Model (hereinafter ESHM20) the outcome of the SERA JRA3 will be distributed throughout the EFEHR web-platform. Currently, the EFEHR web platform distributes the seismic hazard models for: the 2013 European Seismic Hazard Model (ESHM13, Wössner et al 2015), the 2014 Earthquake Model of the Middle East (EMME14, Giardini 2018), the 2015 Swiss Hazard Model (SuiHaz15, Wiemer et al 2015), and the 1999 Global Hazard Map of the Global Seismic Hazard Assessment Program (GSHAP, Giardini 1999).

Note, that the web-portal of EFEHR provides also access to all the main ingredients of the seismic hazard model (i.e. earthquake catalogues, datasets of active faults, seismogenic source models, ground motion datasets), seismic hazard results, hazard input files to repeat the hazard calculation (OpenQuake, Pagani et al 2014). All these components are documented and links to external compiles of the original data sources are provided.

The EFEHR web platform mounts three stand-alone web applications for interactively discovering and retrieving hazard curves (Figure 1, top), and hazard spectra (Figure 1, mid) and hazard maps (lower, Figure 1). The new layer manager of the Hazard Curve and Spectra web applications is fully customizable allowing the addition of a hazard map, input datasets and/or control different transparency levels. Moreover, there is an option to select hazard curves and or hazard spectra for different models valid at the site location of interest for comparison purposes. The background layers allow adding Open Source Map content, country boundaries and control the transparency of these layers. Additional layers can be added to the map view to illustrate some of the main components of the hazard model: earthquake catalogue, active faults and the source zonation. A log panel is located at the bottom of the web page. It provides a summary of the model query parameters and a URL link to download the selected data.

The hazard map viewer has been updated to a new interface and a layer manager (same as for spectra). The layout of the webpage has been preserved, with the model selection consisting of drop-down menus on the left hand-side. The menu bar appears in all data viewers except the documentation section. Map Controls allows controlling the map viewer, and Print allows one to print the entire web-page and/or a selected area. The Map Legend is located on the right-hand side of the webpage, indicating the color bar of the selected hazard maps. By default, the background layers are illustrating the country boundaries, the geo-reference of Europe from Open Street Maps and the transparency controllers of all layers

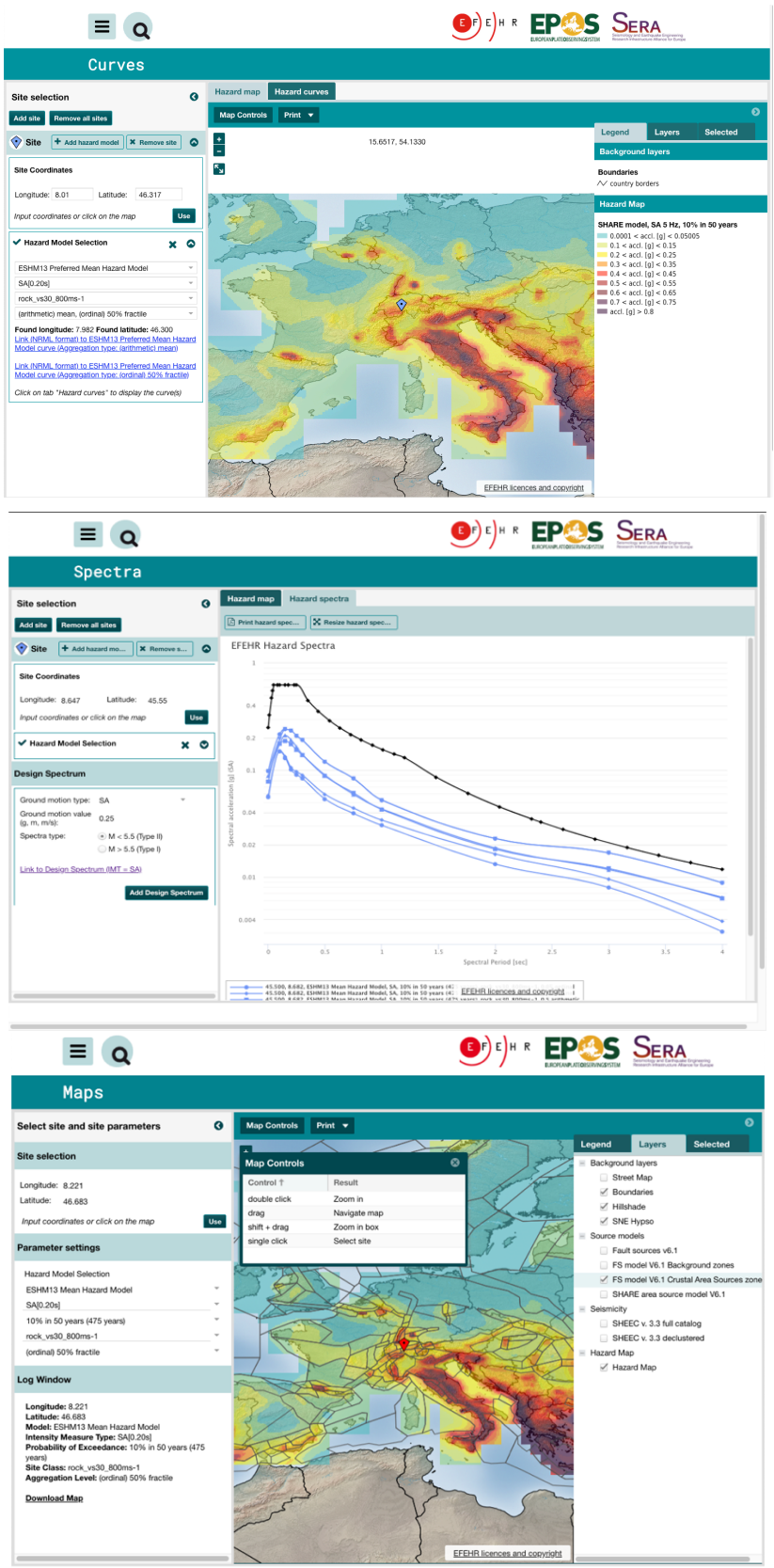

Figure 1: EFEHR web-portal: hazard curve viewer (top) and hazard spectra viewer (middle) and hazard map (bottom)

Viewers retrieve hazard data (as well as metadata on available models and parameters) using a restful web service API. The API is public and can be used directly by researchers to programmatically retrieve data. A WADL (Web Application Description Language) definition allows automatic generation of web service clients for several modern programming languages. An example of such a client in MATLAB is distributed by EFEHR (http://www.efehr.org/en/Documentation/web-services/data-access-via-matlab/). Another example is a Python script developed at Royal Observatory of Belgium to programmatically access the EFEHR web services: https://github.com/ROB-Seismology/rshalib/blob/master/result/efehr.py .

For hazard maps, parameter discovery is implemented using EFEHR's REST API; maps themselves are shipped via custom services (ASCII data), file download (compressed ESRI(R) shapefiles), and OGC-standardized Web Map Services (projected map images). The full documentation of the REST (Representational State Transfer) API (Application programming interface) is available at http://www.efehr.org/en/Documentation/web-services/.

1. **EFEHR - hazard maps** to provide access to seismic hazard maps of various seismic hazard models (regional - ESHM13, EMME14, GSHAP and national-SuiHaz15). Selection by point of interest or region of interest (user-defined polygon)
2. **EFEHR - hazard curves** to provide access to seismic hazard curves of various seismic hazard models (the 2013 European Seismic Hazard Model, the 2014 Earthquake Hazard Model of the Middle East). Selection by point of interest (user defined)
3. **EFEHR - hazard spectra** services facilitate access to uniform hazard spectra of various hazard models (the 2013 European Seismic Hazard Model, the 2014 Earthquake Hazard Model of the Middle East, GSHAP) for a given location, for various probabilities of exceedance (or mean return periods)
4. **EFEHR - EC8 Elastic Design Spectra**: allows comparison of the hazard spectrum (in acceleration or velocity) predicted by a hazard model to the Eurocode 8 design spectra, we provide a service to retrieve the design spectra (spectral acceleration or spectral velocity) for a given peak ground acceleration.

The active faults datasets will be available via web-services that either hosted by the EFHER web-portal or directly linked to the main repository of the active faults, similarly to the European Database of Seismogenic Faults (EDSF; Basili et al., 2013) compiled during the EU-FP7 Project SHARE. The new EFSM20 will be made available on the internet through the SEISMOFAULTS.EU platform (Figure 2). The SEISMOFAULTS.EU IT infrastructure is entirely built using free and open source software, the data and metadata distribution is made through the Open Geospatial Consortium (OGC) service standard protocols (Vallone et al., 2019).
It hosts one of the main data provisions of EPOS-Seismology and is mapped in the EPOS ICS-C graphic user interface. As part of the EFHER facility for seismic hazard and risk services it delivers fault information tailored to be used as input data for earthquake hazard analyses. The final release of EFSM20 is also suited for being integrated within the interoperable environment of the SERA Virtual Access for Engineering Seismology (VA3; http://sera-va3.rm.ingv.it/) together with the Engineering Strong Motion Database (ESM) and the European Archive of Historical Earthquake Data (AHEAD). To ensure EFSM20 complies with the FAIR initiative, the dataset metadata have been preliminarily submitted to the INGV Data Management Office (Locati et al., 2020) to mint a DOI within the DataCite organization (https://datacite.org/), assign a proper license, and establish the authors' intellectual property rights (Figure 2).

The web-portal provides also link to the risk services hosted at EUCenter, Pavia, Italy (https://eu-risk.eucentre.it) and all relevant webservices are fully documented and available at https://eu-risk.eucentre.it/web-services/. Finally, the EFEHR web-portal provides a single access point for data, models and results. No user authorization is required.

Note, that a final update to the hazard and risk products, following their review and validation by the wider European engineering/risk community, will be released together with the final release of the 2020 European Seismic Hazard (ESHM20) and Risk Model (ESRM20) in autumn 2020.

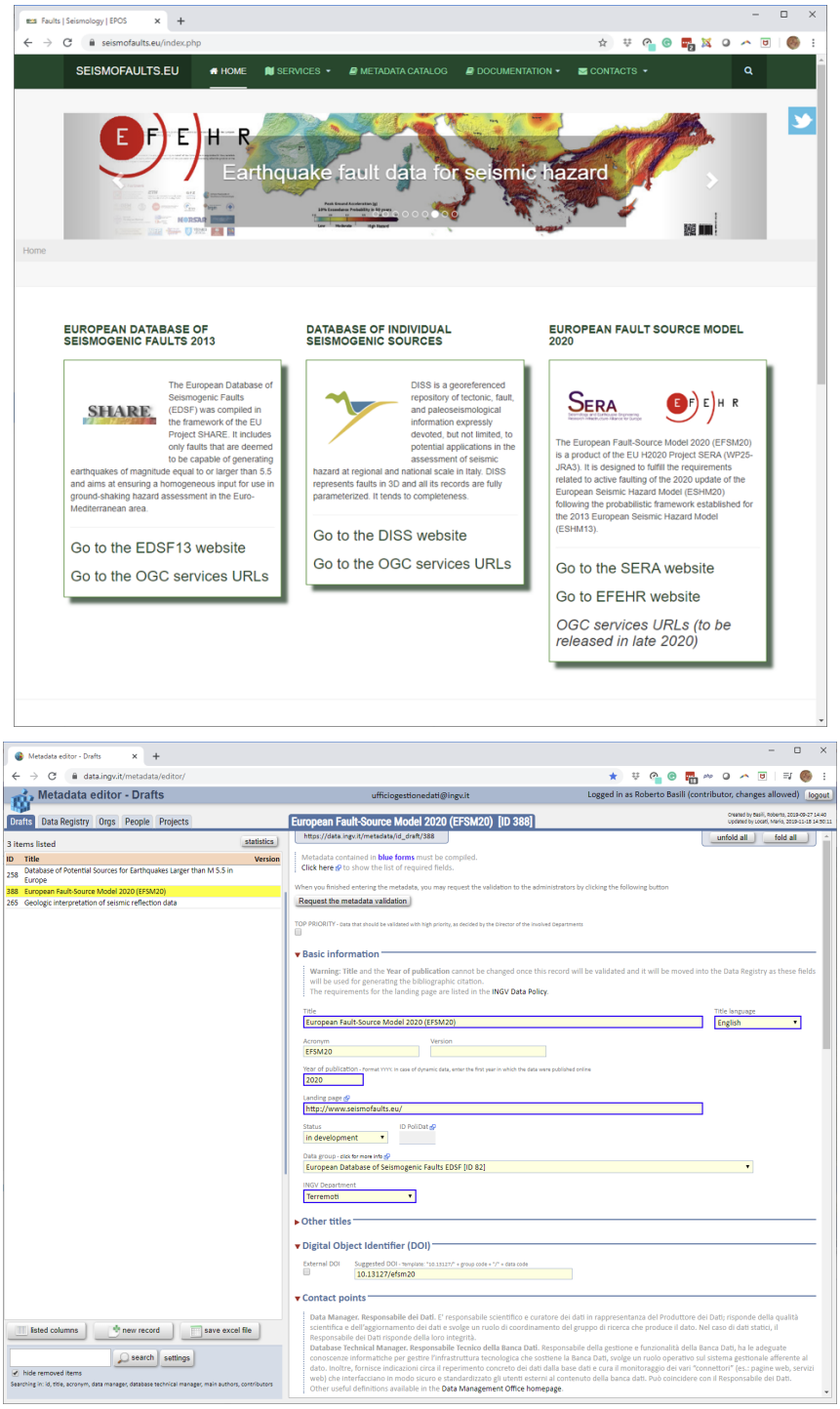

Figure 2: Screenshot of the SEISMOFAULTS.EU web portal which already distributes seismogenic fault datasets through OGC standard protocols (top). Screenshot of the metadata editor provided by the INGV Data Management Office (bottom).

2 ESHM20 Model Documentation

The 2020 Update of the European Seismic Hazard Mode (ESHM20) will be online documented on the documentation section of the EFEHR web-portal. The documentation will follow the same template of the web-page as for the ESHM13 (www. http://www.efehr.org/en/Documentation/about-seismic-hazard/) where the main components of the ESHM20 are listed as shown in the Figure 4. Note that this documentation provides information about the main input models, and components. Each component will have a dedicated web-page, repository and web-services. The documentation of the ESHM20 will be activated when the model will be released (Autumn 2020).

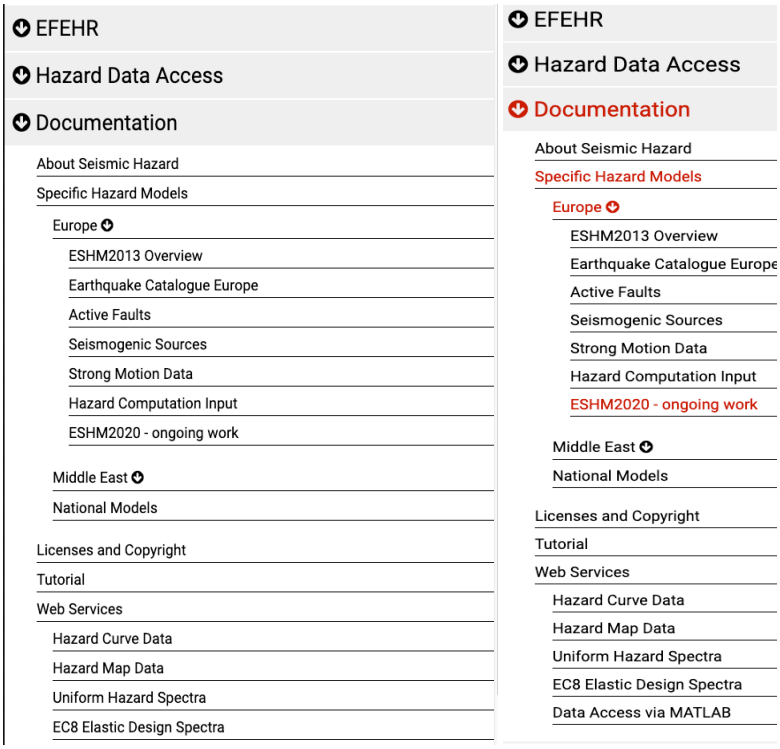

Figure 3: Screenshots of the Documentation Dropdown Menu of the EFEHR web-portal (www.efehr.org) for accessing the main hazard and risk models for Europe. The documentation of the ESHM20 will be activated when the model will be released (Autumn 2020).

A stand-alone report will be provided together with the final release of the ESHM20. The ESHM20 report will be provided with DOI and will describe the main components of the models, details of the model development for full transparence and facilitate the knowledge transfer to the readers.

3 ESHM20 Main Datasets

All key datasets than form the basis for developing the ESHM20 are distributed throughout the EFEHR web-portal. These datasets were compiled in the Joint Research Activities JRA2 and JRA3 of SERA Project. These datasets are summarized in the SERA D25.2 updated M18 and M24, and they can be summarized as: an earthquake unified catalogue, the instrumental (See Section 1.1 of SERA D25.2 update M18, M24) and the historical catalogue (Section 1.2, SERA D25.2 update M18, M24); The unified earthquake catalogue consists of two parts: the so-called instrumental catalogue (after 1900) based on the updated EMEC catalogue (Grünthal G. and R. Wahlström (2012), Grünthal et al 2013, coordinated by GFZ Potsdam, Section 2.6: Seismic Hazard and Risk Dynamics) and developed within SERA - JRA2), and an historical earthquake catalogue (before 1900), based on the SHEEC (Stucchi et al 2013) and coordinated by INGV Milano. Both catalogues are documented in section 1 and 2 of the SERA JRA3 - D25.2. Note, that the main repositories of the instrumental and historical catalogues are the main resource for accessing these datasets; i.e. EMEC main repository (http://emec.gfz-potsdam.de/) and AHEAD main services (https://www.emidius.eu/AHEAD/index.php). The unified catalogue is illustrated in Figure 3.

The active fault database and subduction datasets (Section 2 of SERA D25.2 updated M18, M24). This new dataset (Basili et al., 2020), named European Fault Source Model 2020 (EFSM20), considers two main categories of seismogenic faults: 1) crustal faults; and 2) subduction systems (Figure 5). Crustal faults are represented with a down-dip planar geometry and are meant to model crustal seismicity, whereas subduction systems are represented by a complex 3D geometry of the slab and are meant to model both interface and intraslab earthquakes. The minimum set of basic fault parameters required for constructing a seismogenic source model refer to geometry (location: lat, lon, depth; size: length, width; orientation: strike, dip) and behavior (rake, slip rate or convergence rate, seismic efficiency, rigidity, magnitude upper bound). These are indispensable elements for devising the tectonic and seismic moment rate production and applying to it an earthquake recurrence model to be expressed by a Magnitude-Frequency Distribution (MFD).

EFSM20 is based on several national/regional compilations of active faults recently published by a large community of geoscientists, and several original contributions. The latest update of EFSM20, version 4 as of 06/04/2020, is shown in map view in Figure 6. The actual input for use in ESHM20, however, is made of several files that require further processing of what is shown in this map. For example, the slab interface seismicity model is made of several alternatives derived from this basic input dataset and following an articulated logic tree.

The next type of products to be available are the derived products, such as seismogenic source models: the area source model, the active faults plus the background smoothed seismicity (all summarized in SERA D25.3 update M24 and M36). These products will be provided as a data files for direct download, via web service access. Moreover, the EFEHR web-viewer of hazard maps allows to overlap the seismogenic sources in any hazard map display. Such features are important to identify seismogenic sources their properties and association with ground shaking estimates.

The next category of datasets to be become online available are the seismic hazard results: seismic hazard maps, hazard curves and hazard spectra. A new set of results, not available before are the hazard disaggregation at a given site. In summary the following hazard products (as in SERA D25.7 M36) are:

- European maps of the median elastic spectral acceleration of the response spectrum on reference rock with a Vs30 of 800 m/s for the following periods of vibration: 0.01, 0.1, 0.15, 0.2, 0.25, 0.3, 0.5, 0.75, 1, 2, 3, 4 (s)
- Hazard curves across Europe on reference rock with a Vs30 of 800 m/s for the following periods of vibration: 0.01, 0.1, 0.15, 0.2, 0.25, 0.3, 0.5, 0.75, 1, 2, 3, 4 (s)
- Uniform Hazard Spectra (UHS) across Europe on reference rock with a Vs30 of 800 m/s for the following return periods: 73, 102, 475, 975, 2475, 4975 (years)
- Disaggregation at a number of sites across Europe for each spectral ordinate and return period described above.

Of a particular interest are the two main products to be produced as a basis for an update of the informative annex of Eurocode 8, Part 1). These two products, also summarized in SERA D25.7 are as follows:

- European map of the median elastic spectral acceleration of the plateau[1]* of the response spectrum on reference rock with a Vs30 of 800 m/s.
- European map of the median elastic spectral acceleration at 1 second on reference rock with a Vs30 of 800 m/s.

These new datasets and results are available via web-application or access throughout the web-services. For further information, we refer to http://www.efehr.org/en/hazard-data-access/Intro/. A GitLab repository has also been set up that will store all of the OpenQuake-engine input files, intermediate products and tools used in the risk calculations of ESRM20 (https://gitlab.seismo.ethz.ch/efehr/).

[1] The definition of the plateau of the spectrum is being provided by a working group of CEN/TC250/SC8.

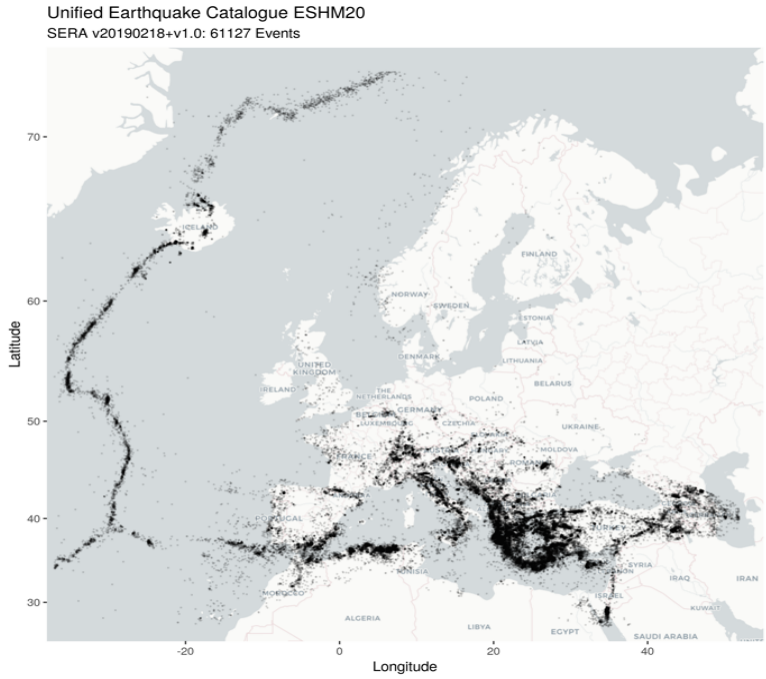

Figure 4: Map view of unified earthquake catalogues ESHM20 (left) combining an instrumental earthquake catalogue derived from EMEC catalogue and a historical earthquake catalogue (Stucchi et al 2013)

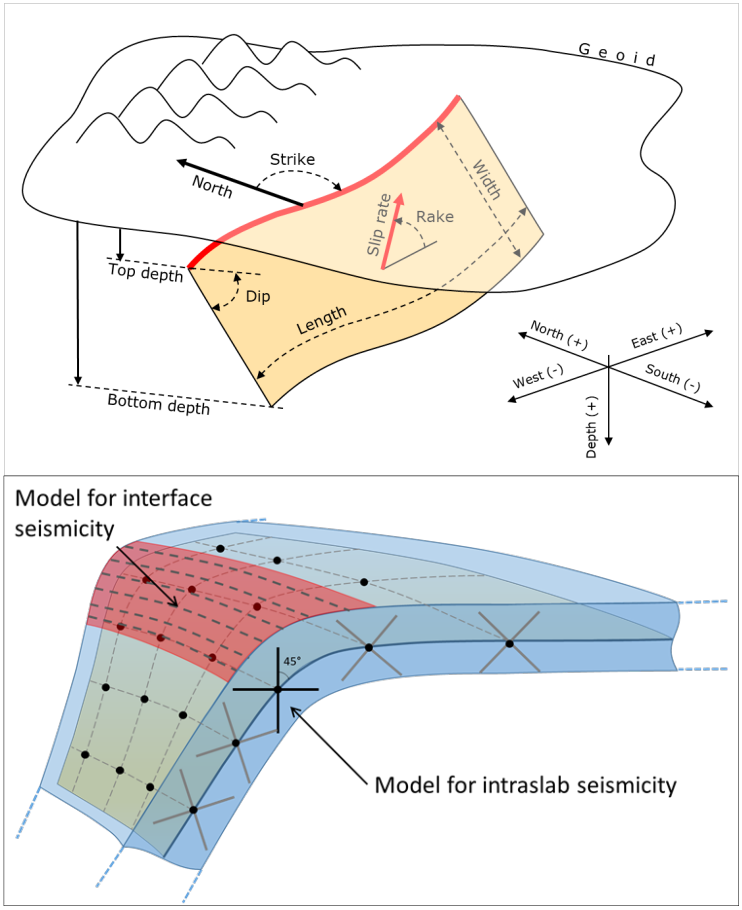

Figure 5: Generalized scheme representing fault sources for the hazard calculations: a crustal seismogenic fault (top) and a subduction system (bottom).

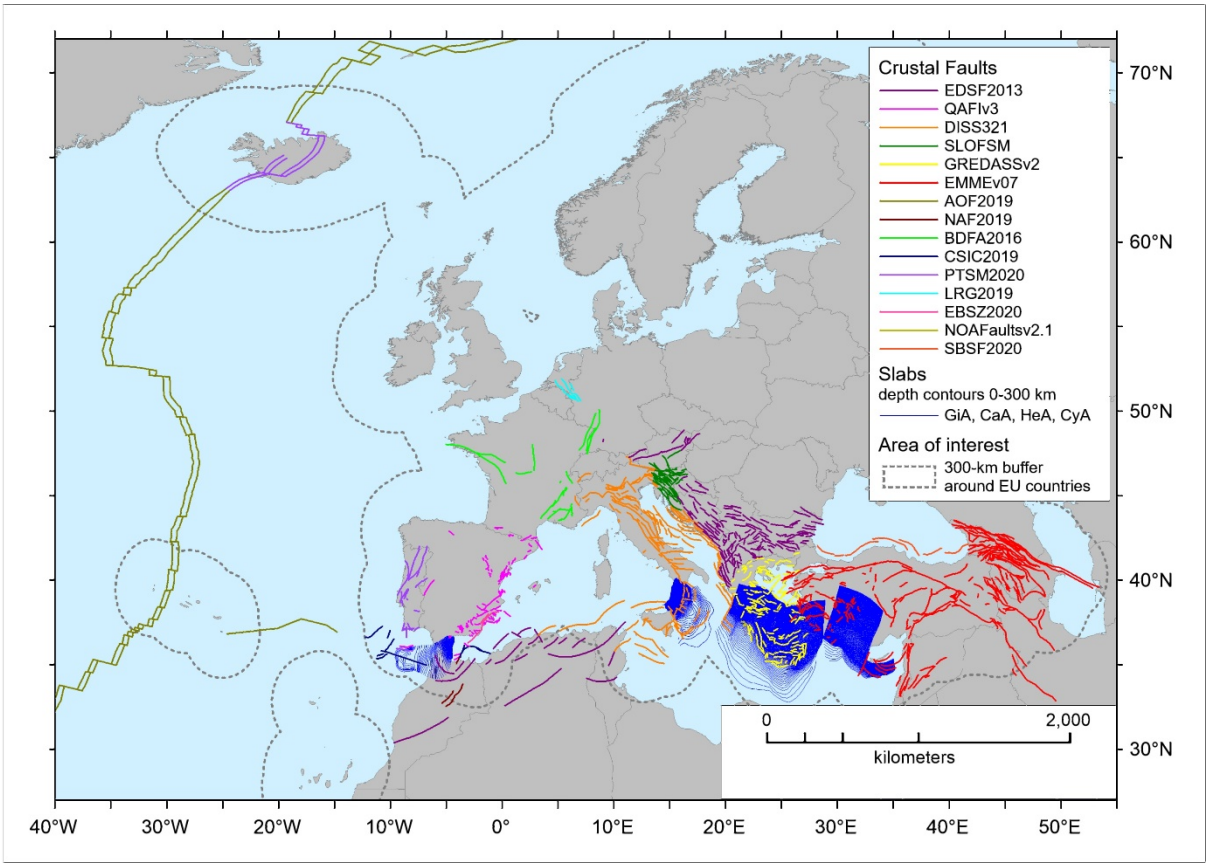

Figure 6: Map view of the EFSM20 crustal faults and subduction systems (version 4, as of 06/04/2020). The colors of crustal faults indicate the provenance dataset. The area of interest, set as a buffer with a radius of 300 km, is shown. Also, the slab depth in subduction system is cut at 300 km.

3.1 Summary of Input Files for OpenQuake

OpenQuake engine (ver. 3.9, https://github.com/gem/oq-engine) is used to compute the 2020 update of the ground shaking hazard for the Euro-Mediterranean region. The input files for OpenQuake were created from the data files of the single source models and the proposed logic-tree for the ground motion prediction equations defining the respective weights.

Input files are in Natural hazards' Risk Markup Language (NRML) format, as described in the OpenQuake User Manual (Pagani et al 2014). The input files reflect the source model and the ground motion logic tree as described in SERA Deliverable D25.3.

4 Appendix: EFEHR Data Management Plan

Data Summary

EFEHR data and models are collected from completed scientific projects for long-term archiving, documentation, accessibility and use in research. Data covers the following domains:

- Observed seismicity / earthquake catalogs
- Seismicity models, including parametrized active faults, seismic zones, and gridded seismicity models, ground motion prediction models, and logic trees of them
- Resulting probabilistic earthquake hazard data, expressed in hazard maps, curves and spectra with reference to different
- Hazard model documentation
- Expert information and best practice documents for probabilistic hazard assessment.

All data comes with original research reports, but homogenized data formats and representations (Natural hazards' Risk Markup Language (NRML), OGC Web Map Services (WMS) response, geospatial vector data format (shapefile, https://en.wikipedia.org/wiki/Shapefile) for geographic information system (GIS) software, open standard to represent seismological data (QuakeML, https://quake.ethz.ch/quakeml/), a variant of eXtensible Markup Language (xml) and tabular ASCII data). Documentation, products and services are mostly addressed to a well-informed public, including researchers and engineers.

FAIR Data Policy

Entire datasets identified by *doi* identifiers and full respective metadata sets. For access to individual data points, a set of EFEHR-specific discovery services (RESTful web service API) is offered. The API is documented in WADL and explanatory text at http://www.efehr.org/en/Documentation/web-services/. An EPOS-DCAT-compatible secondary documentation is in preparation and planned to be available by the end of 2018

Data is accessible as bulk downloads - entire hazard models in OpenQuake input NRML format and maps (ESRI shape format), as individual data points, hazard curves and spectra discoverable and retrievable from a web service API in NRML format, and (for spatial data) via OGC standard WMS (web map service) interface. Thus, all data is in well documented community or industry standard formats. Standard access services are used as far as available; otherwise standards have been defined for EFEHR. All data holdings are freely accessible to unregistered users under the license agreed on with the originating project / initial provider. EFEHR tries to homogenize agreements to the Creative Commons - CC BY SA v4.0 (https://creativecommons.org/licenses/by-sa/4.0) open data license.

Allocation of Resources

- Standard technical operation, knowledge transfer, expertise and a basic infrastructure for quality-controlled seismic hazard/risk assessment are covered by EFEHR being one of the long-term strategic pillars of the European Plate Observatory EPOS, and backed up by ETH/SED. IT support and maintenance is covered by standard SED IT operations and the respective maintenance and 24/7 service team. Project specific scientific support, research task, and development of new services follow a long-term plan, but are financed on a project basis.

Data Security

- Data preservation and disaster recovery is granted by two daily off-site backups of both data holdings and virtual service infrastructure, with a preservation time of 3 months. Database integrity, service stability and access control is granted by a 3-layer system architecture (database/data holdings <-> access services <-> web layer) with firewalled interconnects and full logging on the upper two layers.

- Service continuity is supported by a 24/7 it monitoring & intervention team at best effort. However, there is no formal service availability level is guaranteed.

Ethical Aspects

EFEHR does not hold individual or personalized data in its scientific content, nor request or log such data from users.

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