SEISMIC SHAKE 2.0 APP: DATA AND TOOLS TO CONTRIBUTE TO REDUCING SEISMIC RISK

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Abstract: *Seismic Shake-e 2.0 (SSe) is a freeware app developed to divulge some relevant efforts performed in the world to improve our capacity to resist the adverse effects that some earthquakes can eventually produce. At the same time, SSe includes some tools for processing seismic ground motion data. SSe was one of the apps selected in the EOVALUE call (Joint Research Center, 2019). One of the purposes of SSe is to contribute to the holistic analysis of seismic risk. SSe has six modules for both basic and intermediate-advanced users. For the basic users, the modules available are: a) Where usually do earthquakes occur? How do we measure the features of earthquakes? b) What is a seismic record, and how can we process it? c) Why is the seismic design of buildings so important? d) How do we assess the features of future earthquakes that can occur in a region? e) What an Earthquake Early Warning System is? F) What services can be used to verify in a short time damage triggered by a recent earthquake? Similarly, for the intermediate-advanced users, the modules available are the following: a) Accelerometers Networks (AN); b) Seismograms Analyzer-e (SA-e); c) Seismic Design of buildings (SDB); d) Earthquake Preparedness (EP); e) Earthquake Early Warning Systems (EEWS) & Tsunami Warning Systems; f) Earthquake Emergency; Response & Recovery (EERR). The main objectives in the AN module of SSe are the following: a) contributing to disseminating reliable sources of information about accelerometers networks in the world and b) highlighting examples of accelerometer networks in the world. SSe incorporates the Seismograms Analyzer-e module to analyze accelerograms to obtain various earthquake engineering products (response spectra, etc.). The SDB module includes a section with examples of seismic codes developed in the world. It contains examples of city, national, and European codes to highlight how the efforts are performed at different administrative levels. The EP module describes the information to consult or determine seismic hazards in regions. This module highlights relevant projects and software oriented to these purposes as the GEM project and the R-CRISIS software, respectively. The EEWS underlines successful Earthquake Early Warning Systems, as in the Mexican case. Finally, the EERR module describes valuable services to attend emergencies and to contribute to improving the response and recovery task. Mainly, it describes the Copernicus Emergency Management Service.*

1 Seismic Shake-e

Seismic Shake-e is an app oriented to contribute to divulging relevant efforts developed in the world to improve our capacity to resist the adverse effects of some earthquakes. SSe was one of the apps selected in the EOVALUE call (Joint Research Center, 2019). SSe is an app that contains both information and tools. Figure 1 shows the main screen of Seismic Shake-e.

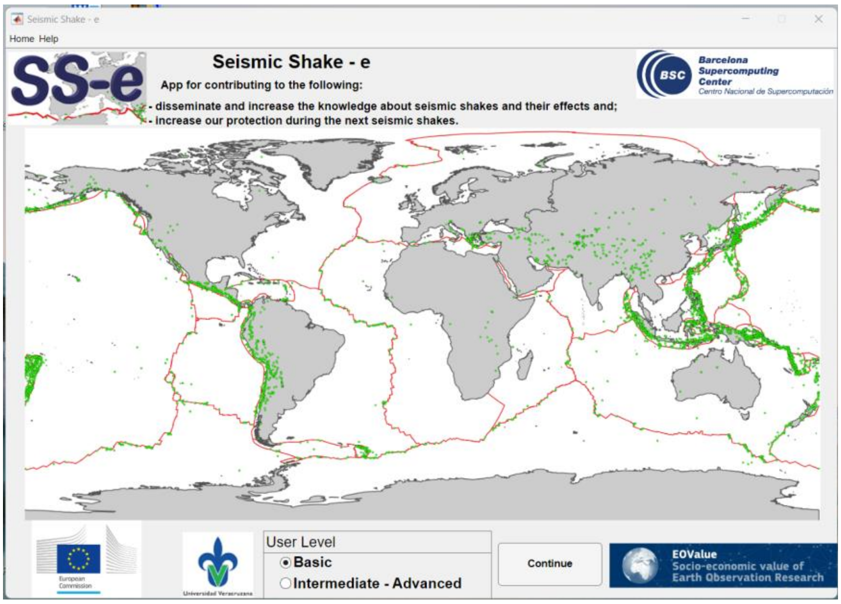

Figure 1. The main screen of Seismic Shake-e

2 Essential elements of Seismic Shake-e

2.1. Intermediate and advanced options

Figure 2 shows the six modules that are available for the intermediate-advanced users of SSe: a) Accelerometers Networks; b) Seismograms Analyzer-e (SA-e); c) Seismic Design of buildings; d) Earthquake Preparedness; e) Earthquake Early Warning Systems & Tsunami Warning Systems; f) Earthquake Emergency; Response & Recovery.

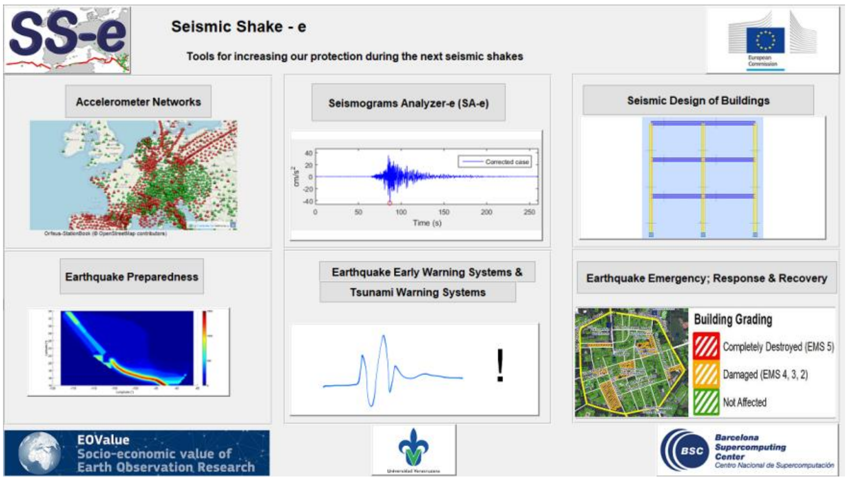

Figure 2. The main screen of the modules for intermediate-advanced users of SSe

2.1.1. Accelerometer Networks

The main objectives in the AN module of SSe are the following: a) contributing to disseminating reliable sources of information about accelerometers networks in the world, b) highlighting examples of accelerometer networks in the world. For the purposes above, the AN module contains the links to the FDSN networks database (Suárez et al, 2008) and the European Station Book Portal (Orfeus Foundation, 2021). Additionally. The AN module includes five examples of Accelerometer Networks. For each one of them, three data sources are included: i) Original source, ii) Orfeus Data Center source, and iii) FDSN source. For instance, for the Italian National Seismic Network (INSN), the original source allows opening the official site of the INSN, which is a site that contains the original data of INSN. Initially, this site shows a map with the seismic stations of the network and a list of each station. The site also indicates which are active stations and which are not. At the same time, detailed data on each seismic station can be obtained on this site. The Orfeus Data Center source also contains detailed information on the INSN, with some differences in the format used to show the data and some distinctions in the shown data. For instance, for the INSN in the Original Source, the sample rate of each sensor of the chosen seismic stations is shown. However, the Orfeus Data Center site also included the input unit's name. Therefore, some of the data from these two sources are complementary information. Finally, the FDSN source contains a summary of the Network selected.

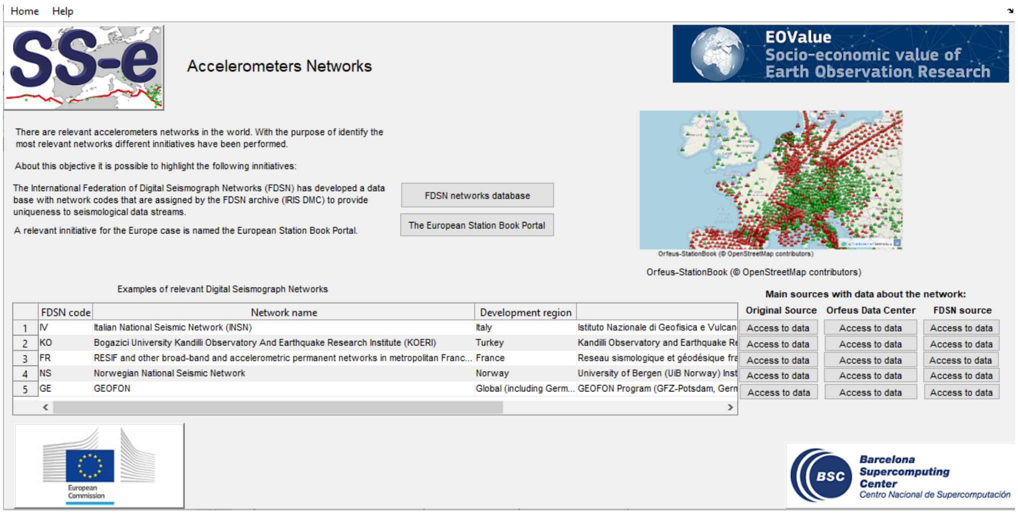

Figure 3. The main screen of the Accelerometer Networks module of SSe is for intermediate or advanced users.

The information sources mentioned in the SS-e allow identifying the location of each network's seismic station and which seismic stations are in operation. This information is relevant because a problem that exists is the fact that nowadays, there are regions in the world that do not have an accelerometer network. For instance, even though there are important seismic networks in Mexico, at the same time, there are regions of the country that do not have public seismic stations (SSN, 2021; RESNOM, 2021). The detailed information about the examples of accelerometer networks included in SSe allows observe that some accelerometer networks have seismic stations in different countries as the GEOFON (GE) network (Figure 2). This network has stations, for instance, in Germany, Italy, Portugal, Chile, Argentina, etcetera (https://geofon.gfz-potsdam.de/). This type of global accelerometers network is a possible option for accessing seismic records in some countries that do not have their accelerometer network.

The first example included in Figure 2 of a digital seismograph network is the Italian National Seismic Network. Three links are included from each of the five examples in the AN module: Orfeus Data Center, Original Source, and FDSN source. In the case of the Italian Network, the FDSN source includes a summary of the networks and the link to the original Italian source. In the Orfeus Data Center and the Original Source for the same case of the Italian Network, it is possible to identify that the information of both sources is not the same. In fact, there is complementary information in both sources. For instance, in both sources, there is a list of the available seismic stations. However, the specific data about each seismic station have some differences. Specifically, the Orfeus Data Center contains the type of input data of each station that is not mentioned in the summary of each station in the Original Source. Therefore, in cases such as the Italian cases the information of the Orfeus Data Center and the Original Source is complementary. For these types of reasons, the SSe includes these three information sources.

2.1.2. Seismograms Analyzer-e

The seismic records are fundamental data to learn about earthquakes. For this purpose, SSe incorporates a module to analyze accelerograms. As a basic example, the SA-e module includes examples of seismic records. However, it is also possible to analyze external seismic records.

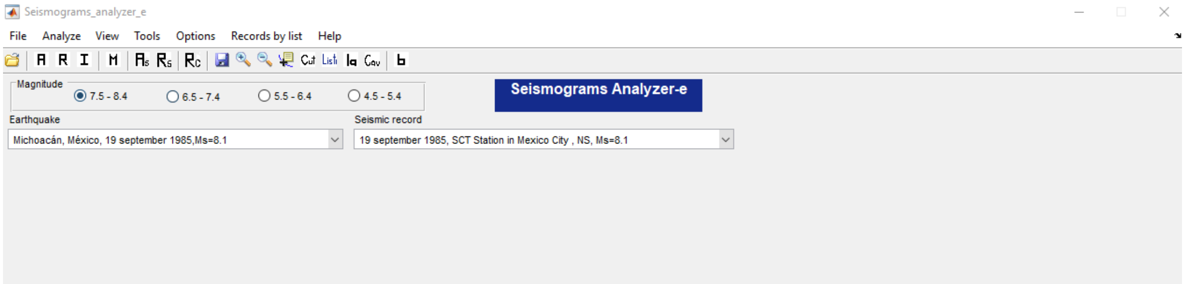

Figure 4. The main screen of the Seismograms Analyzer-e module of SSe is for intermediate or advanced users.

2.1.3. Seismic design of buildings

This module includes a section with examples of seismic codes developed in the world (Figure 4). The module includes city codes, national codes, and European codes to highlight how the efforts are performed at different administrative levels. For instance, the module shows the reference of the seismic code of Mexico City, which includes a website to compute the seismic actions that must be considered to design new buildings in this city. The seismic provisions of Mexico City represent a valuable example of relevant results of a city in the development of its seismic code. In this city, the seismic provisions have been incorporated since the building code of 1942 year (Fajfar, 2018) until the current seismic code that was published in 2020 (NTCDS, 2020). As a national seismic provision, SSe includes references to the cases of Spain (Ministerio de Fomento, 2009), Italy (NTC, 2018), USA (FEMA, 2015a,b), Switzerland (SIA, 2003), and Colombia (NSR-10, 2010). Moreover, as a regional code, SSe includes the case of the European Union, where there is a seismic code called Eurocode 8 for the whole countries of the European Union. However, to consider the regional features as the seismic hazard of each country, Nationally Determined Parameters (NDP) are required. Nowadays, only 63% of the countries of the European Union have defined their Nationally Determined Parameters (Joint Research Center, 2021). It is essential to consider that the Eurocode 8 was published in 1998. Therefore, the absence of Nationally Determined Parameters (NDP) in some countries prevents the application of the Eurocode during the seismic design of Buildings. Usually, in these last cases, they have been applying their national seismic code. It is important to underline, for instance, that Italy has not determined the required parameter to apply Eurocode 8 (Joint Research Center, 2021). However, as was mentioned previously, Italy has recently updated its national seismic code (NTC, 2018).

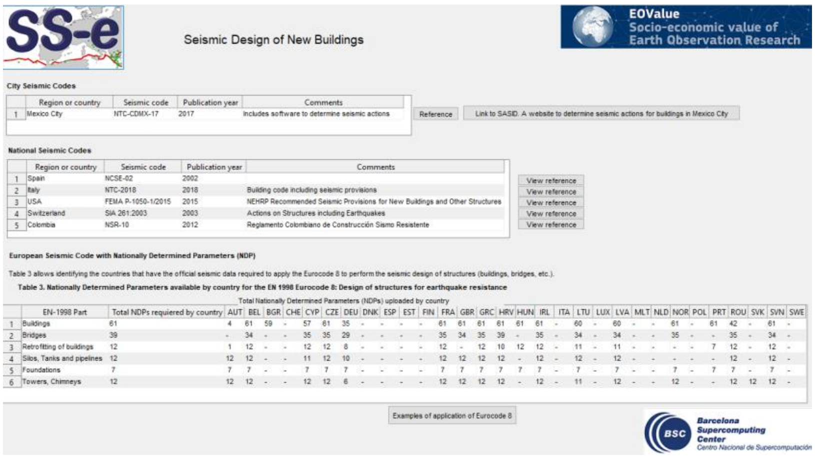

Figure 5. The main screen of the section on the Seismic Design of New Buildings is part of the Seismic Design of Buildings module.

Additionally, the Seismic Design of Buildings module includes a section related to the seismic codes for existing buildings (Figure 5). It includes examples of codes of the USA (IEBC, 2018; ASCE/SEI 41-17, 2017) and New Zealand (NZSEE, 2017). In this case, the inclusion of this section highlights the existence of this type of code and the necessity of developing this class of code in more countries.

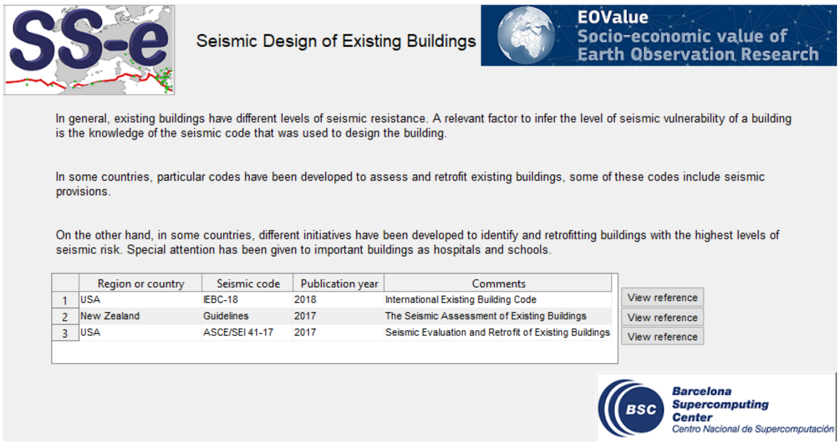

Figure 6. The main screen of the section of seismic codes for existing buildings.

2.1.4. Earthquake Preparedness

The earthquake preparedness module underlines valuable information that has been developed in three relevant aspects of seismic resilience: the seismic hazard, the seismic vulnerability, and the seismic risk (Figure 6). In the seismic hazard section, a collection of two world maps and a European map developed in different years are shown (Figure 7). These maps are an example of preparation for studying the probability of occurrence of seismic intensities for a return period of 475 years. Different world maps of seismic hazard have been published in the last years (Giardini et al, 2003; Ordaz et al, 2014; Pagani et al, 2018). SSe includes two world maps of seismic hazard, which highlight the fact that we have available a reasonable assessment of the seismic hazard in the world since several years ago. An affirmation can be confirmed by comparing the world maps included in this section published in 1999 (Giardini et al, 2003) and 2018 (Pagani et al, 2018). At the same time, these maps underline the importance of continuing to support research projects that have a global interest as the GEM project (Pagani et al, 2018).

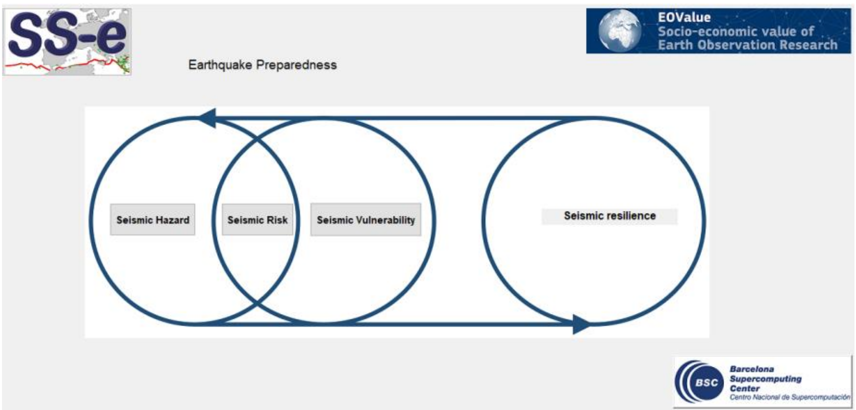

Figure 7. The main screen of the Earthquake Preparedness module of SSe

The section on Seismic Hazard of this module of SSe shows examples of seismic hazard maps that are frequently used to communicate the main results of seismic hazard. At the same time, this module has links to different tools developed to analyze with more detail some of the seismic hazard maps computed. For instance, it includes the link to the map viewer online of the GEM project (Pagani, 2018) and the map generator of the GSHP project (GFZ, 2021). This last GSHP tool allows to generate seismic hazard maps for different regions with different formats (PostScript, PDF, and JPEG), and it allows to download the data in ASCII format to generate the map in external software (GFZ, 2021).

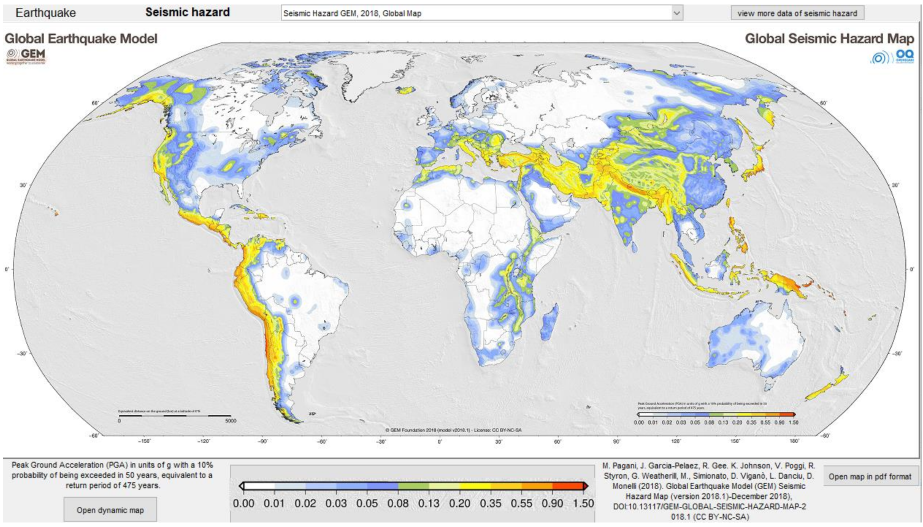

Figure 8. The main screen of the seismic hazard section of the Earthquake preparedness module of SSe

The seismic vulnerability of buildings on an urban scale can be assessed with different methodologies (Calvi et al, 2006; Kassem et al, 2020). For instance, some of these methodologies are known as the vulnerability index methodologies (Aguilar-Meléndez et al, 2019a, Kassem et al, 2020). The vulnerability section of the Earthquake Preparedness software includes an example of a seismic vulnerability map (Figure 8) computed according to the probabilistic version of the vulnerability index method (Aguilar-Meléndez, 2011; Aguilar-Meléndez et al, 2019a, 2019b, 2021).

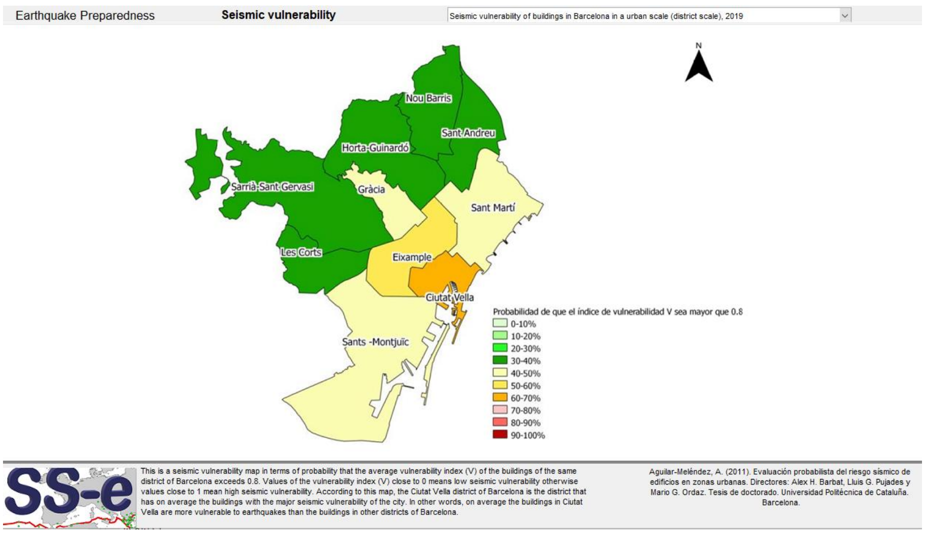

Figure 9. The main screen of the seismic vulnerability section of the Earthquake preparedness module of SSe

As an example of a seismic risk map, the Earthquake Preparedness section of the SSe includes the Global Seismic Risk Map computed as a part of the GEM project (Silva et al, 2018). In this map, the risk in terms of average annual loss (USD) is normalized by the construction cost (USD/m2) (Silva et al, 2018). Usually, to assess the seismic risk of buildings in cities it is necessary to have data of the buildings of the studied cities. However, this data is sensible information that is available only in some cases. Therefore, it is necessary to verify the confidence of the data of the buildings in each seismic risk map published. For this reason, even though the seismic hazard maps of the same region computed in different projects usually have important similitudes, the seismic risk maps for the same regions could have significant differences.

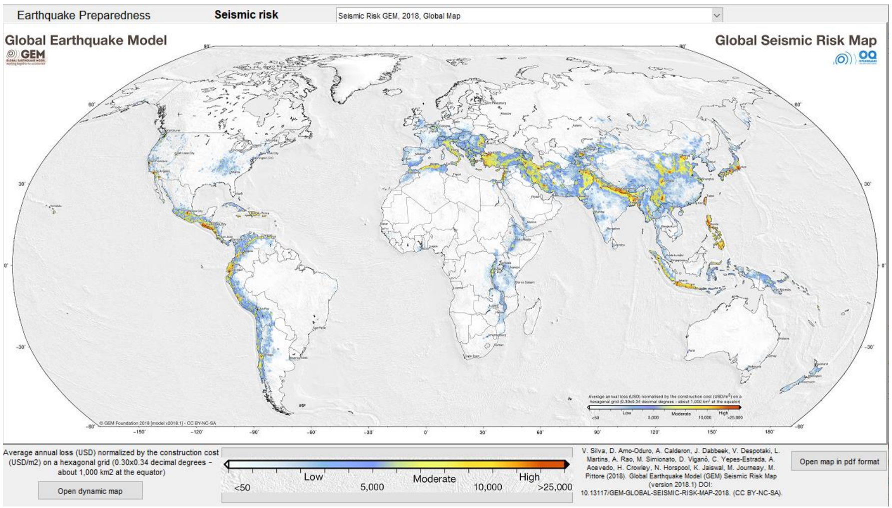

Figure 10. The Main screen of the seismic risk section of the Earthquake preparedness module of SSe

2.1.5. Earthquake Early Warning Systems & Tsunami Warning Systems

SSe contains a module called Earthquake Early Warning Systems (EEWS), which shows examples of relevant EEWS in the world. For instance, it includes the Mexican case called "Sistema de Alerta Sísmica Mexicano (SASMEX®)" (Suarez et al, 2018). SASMEX is a successful example of an EEWS. For instance, during the Chiapas earthquakes (M=8.1) of 7 September 2017, an early warning was automatically generated by SASMEX providing a preparing time of 15 s to the city of Oaxaca, 68 s to the city of Puebla, and 92 s to Mexico City (SASMEX, 2021)

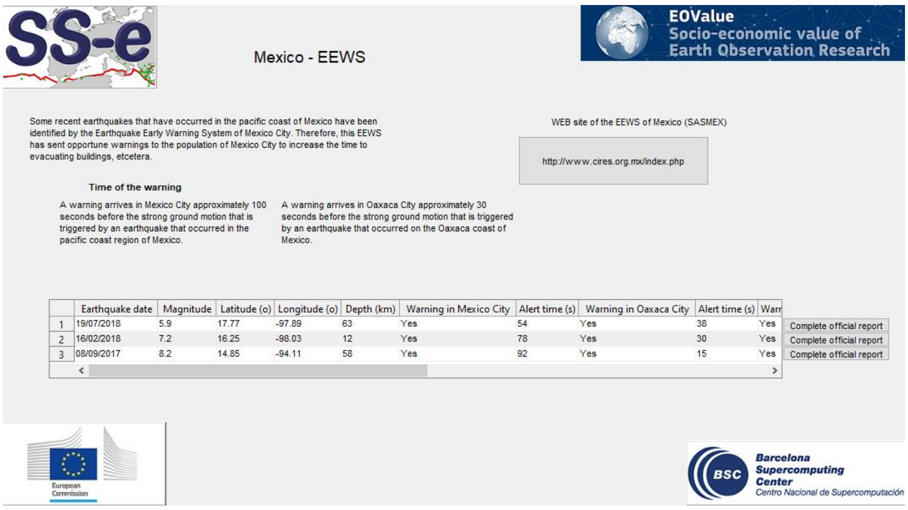

Figure 11. The main screen of the earthquake early warning system of Mexico included in the EEWS module of SSe

Tsunamis are a possible consequence of some earthquakes. Therefore, SSe includes references to Tsunami Warning Systems. Particularly, it includes as examples the Tsunami Warning System of Japan (Tatehata, 1997) and the U.S. Tsunami Warning System (Angove et al, 2015). The catastrophic tsunami due to the 2011 Tōhoku earthquake underlines the importance of continuing to study earthquakes and tsunamis (Kontar et al, 2016).

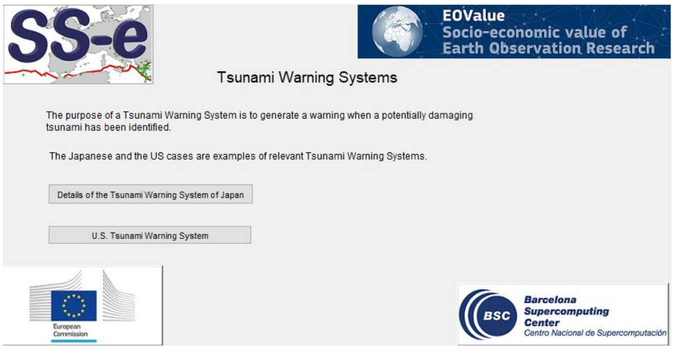

Figure 12. The main screen of the Tsunami early warning system of SSe

2.1.6. Earthquake Emergency; Response & Recovery

SSe includes examples of valuable efforts that have been made in order to contribute to improving the response and recovery after a damaging earthquake. For instance, Figure 12 shows an example of a map developed after a damaging earthquake-affected to San Felice Sul Panaro in Italy due to the 20th May earthquake of 2012. This map was developed based on satellite pictures. The map of Figure 12 was developed by the Copernicus Emergency Management Service (C-EMS, 2021).

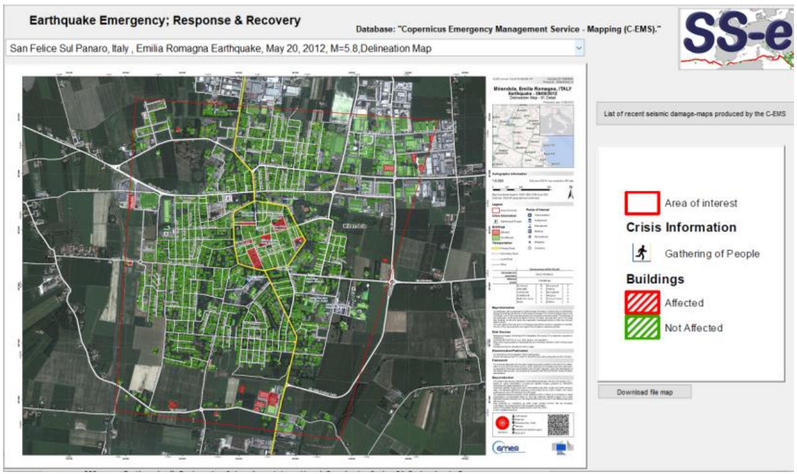

Figure 13. Screen of the Earthquake Emergency; Response & Recovery of SSe

2.2. Basic modules

The main topics considered for intermediate-advances users have been maintained for basic users (Figure 14). However, in general the topics are analyzed with more simple data.

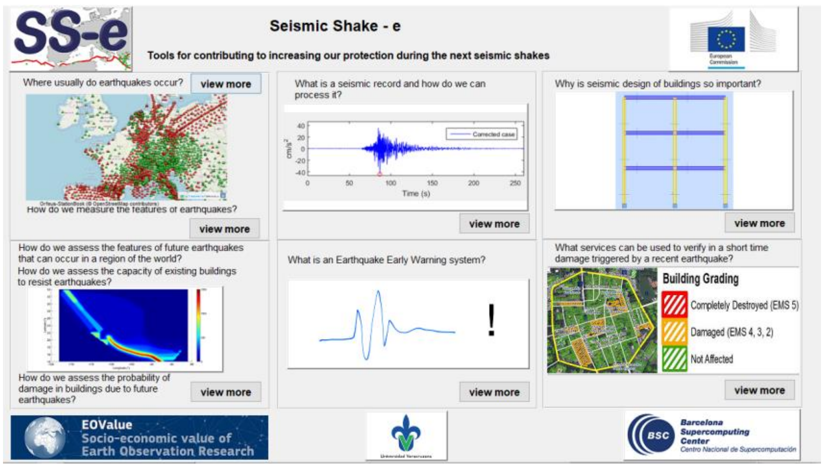

Figure 14. The main screen of the modules for basic users of SSe

For the beginners users the module of earthquakes offers basic information oriented to answer where the earthquakes occur? Where are the limits of the main tectonic plates located? Etcetera

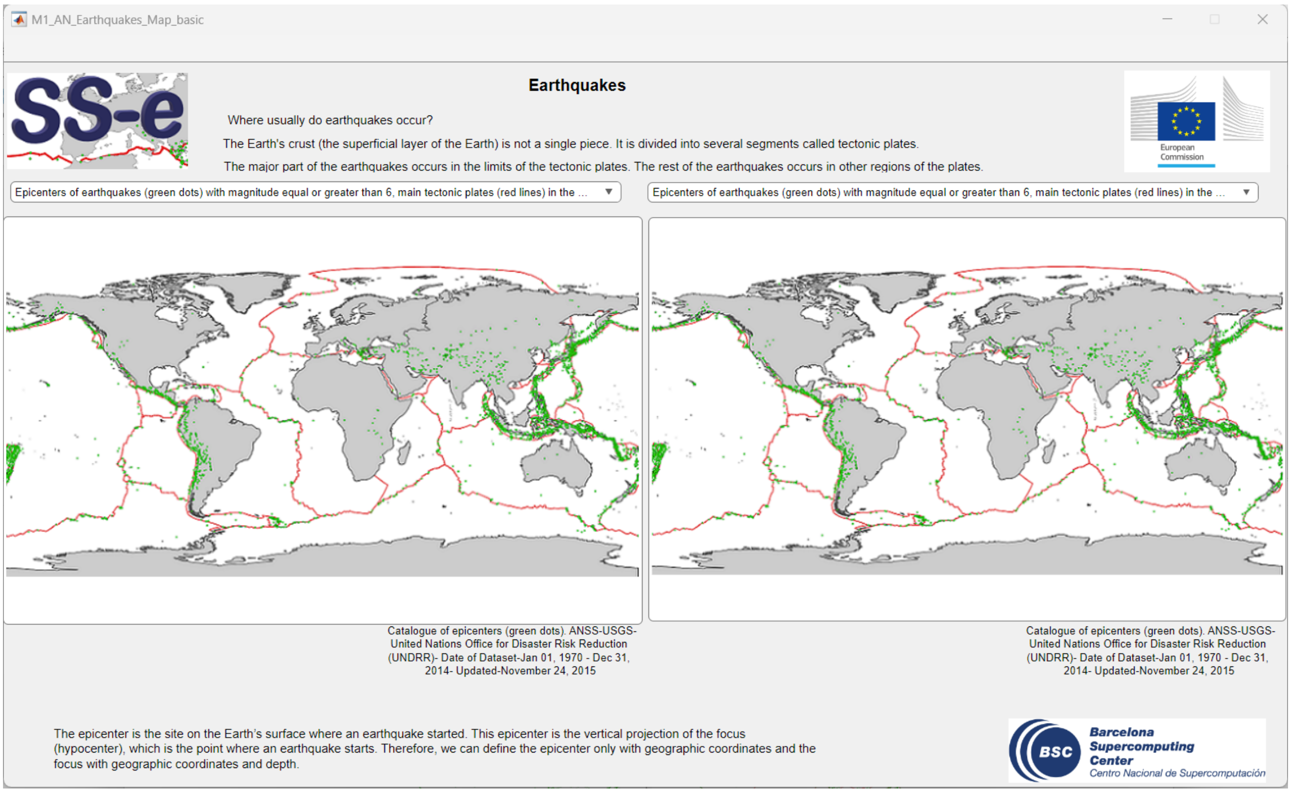

Figure 15. One of the main screens of the earthquakes module for beginners users of SSe

Similarly, a basic version of the seismograms analyzer-e app is included in the Seismic records module for the beginner users (Figure 16).

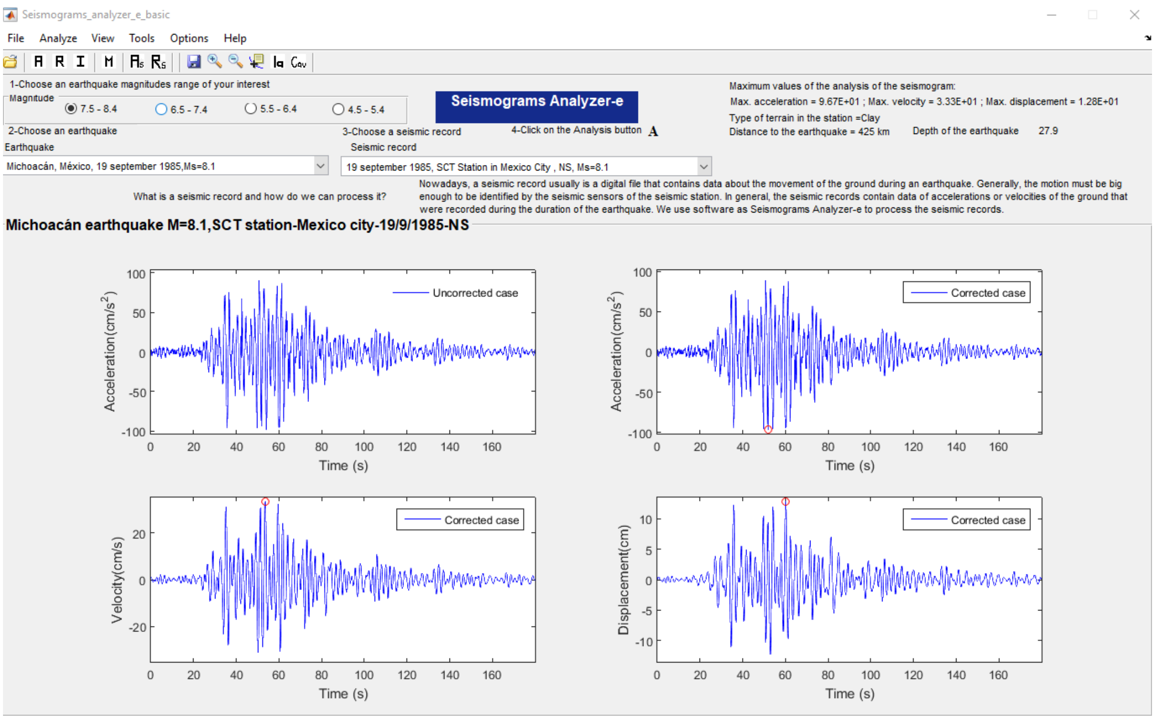

Figure 16. The main screen of Seismic Shake-e for the basic module of seismic records

In the Seismic Design of Buildings module, a basic explanation about the seismic design of buildings is included (Figure 27).

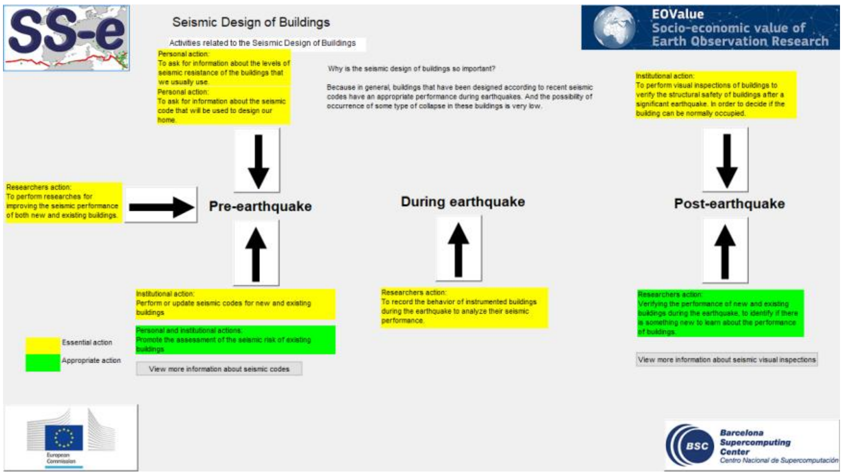

Figure 17. The main screen of Seismic Shake-e for the basic module of seismic design of buildings

In the preparedness basic module, the user can observe and compare the seismic hazard maps for Mexico for different return periods (Figure 18).

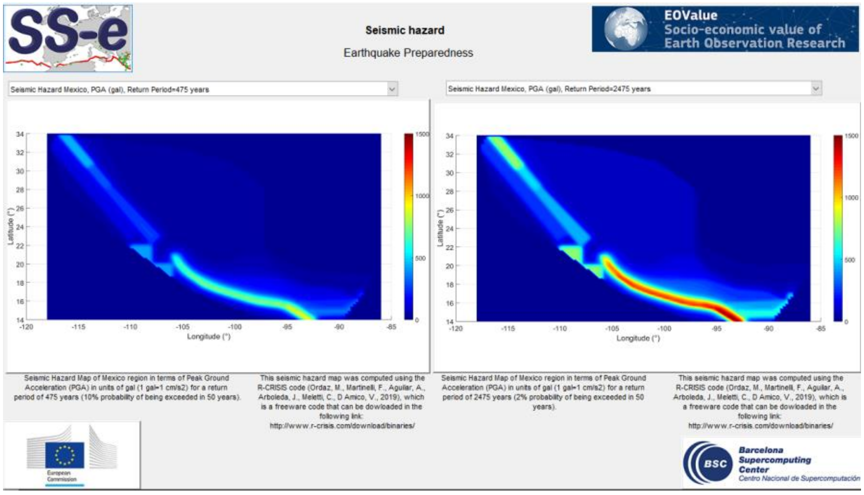

Figure 18. The main screen of Seismic Shake-e for the basic module of earthquake preparedness

On the other hand, for the basic module of Earthquake Early Warning System basic data about the most important EEWS are included (figure 19).

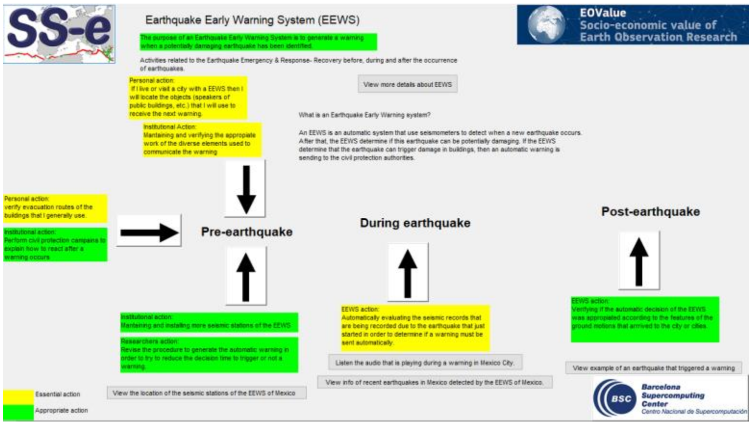

Figure 19. The main screen of Seismic Shake-e for the basic module of Earthquake Early Warning System

3 References

Aguilar-Meléndez A (2011). Evaluación probabilista del riesgo sísmico de edificios en zonas urbanas. Tesis doctoral. Universidad Politécnica de Cataluña, 297. https://www.tdx.cat/handle/10803/668388

Aguilar-Meléndez A, Pujades LG, Barbat AH, Ordaz MG, de la Puente J, Lantada N, Rodríguez-Lozoya HE (2019a) A probabilistic approach for seismic risk assessment based on vulnerability functions. Application to Barcelona. Bullet Earth Eng. 17(4) 1863-1890. https://doi.org/10.1007/s10518-018-0516-4

Aguilar-Meléndez A, Pujades LG, de la Puente J, Barbat AH, Ordaz MG, González-Rocha SN, Welsh-Rodríguez CM, Rodríguez-Lozoya HE, Lantada N, Ibarra L, García-Elías A, Campos-Rios A (2019b). Probabilistic assessment of seismic risk of dwelling buildings of Barcelona Implications for the City Resilience. In: Brunetta G, Caldarice O, Tollin N, Rosas-Casals M, Morato J (eds) Urban resilience for risk and adaptation governance: theory and practices. Springer, Dordrecht. https://doi.org/10.1007/978-3-319-76944-8_13

Aguilar-Meléndez, A., Pujades, L.G., Barbat, A.H. et al. (2021). Comparative analysis of a new assessment of the seismic risk of residential buildings of two districts of Barcelona. Nat Hazards https://doi.org/10.1007/s11069-021-05006-y

Angove M.D., Rabenold C. L., Weinstein S. A., Eblé M. C. and Whitmore P. M. (2015) "U.S. tsunami warning system: Capabilities, gaps, and future vision," OCEANS 2015 - MTS/IEEE Washington, pp. 1-5, doi: 10.23919/OCEANS.2015.7404636.

ASCE/SEI 41-17 (2017) Seismic Evaluation and Retrofit of Existing Buildings. American Society of Civil Engineers. Structural Engineering Institute.

Calvi, G. M., Pinho, R., Magenes, G., Bommer, J. J., Restrepo-Vélez, L. F., & Crowley, H. (2006). Development of seismic vulnerability assessment methodologies over the past 30 years. ISET journal of Earthquake Technology, 43(3), 75-104.

C-EMS (2021). Copernicus Emergency Management Service. https://emergency.copernicus.eu/mapping/copernicus-emergency-management-service#zoom=2&lat=16.54693&lon=10.87901&layers=0BT00

Fajfar P. (2018) Analysis in Seismic Provisions for Buildings: Past, Present and Future. In: Pitilakis K. (eds) Recent Advances in Earthquake Engineering in Europe. ECEE 2018. Geotechnical, Geological and Earthquake Engineering, vol 46. Springer, Cham. https://doi.org/10.1007/978-3-319-75741-4_1

FEMA (2015a) NEHRP Recommended Seismic Provisions for New Buildings and Other Structures. FEMA P-1050-1. Volume I: Part 1 Provisions, Part 2 Commentary https://www.fema.gov/sites/default/files/2020-07/fema_nehrp-seismic-provisions-new-buildings_p-1050-1_2015.pdf

FEMA (2015b) NEHRP Recommended Seismic Provisions for New Buildings and Other Structures. FEMA P-1050-1. Volume II: Part 3 Resource Papers. https://www.fema.gov/sites/default/files/2020-07/fema_nehrp-seismic-provisions-new-buildings_p-1050-2_2015.pdf

GFZ (2021). The global Seismic Hazard map Online. GFZ. Helmholtz Centre. Postdam. http://gmo.gfz-potsdam.de/pub/GSHAP_Map_Online/gshap_map_online_frame.html

Giardini, D., Grünthal, G., Shedlock, K. M. and Zhang, P. (2003): The GSHAP Global Seismic Hazard Map. In: Lee, W., Kanamori, H., Jennings, P. and Kisslinger, C. (eds.): International Handbook of Earthquake & Engineering Seismology, International Geophysics Series 81 B, Academic Press, Amsterdam, 1233-1239.

IEBC (2018) International Existing Building Code. International Code Council.

Joint Research Center (2019) EOVALUE: Call for Innovative Apps in the environmental and social domains. European Commission. https://ec.europa.eu/jrc/communities/en/community/eovalue/news/eovalue-call-innovative-apps-environmental-and-social-domains

Joint Research Center (2021) Eurocodes. Building the Future. Implementation. Uploading of NDPs by countries. European Commission. https://eurocodes.jrc.ec.europa.eu/showpage.php?id=371

Kassem MM, Nazri FM, Farsangi EN (2020) The seismic vulnerability assessment methodologies: a stateof-the-art review. Ain Shams Eng. J. 11(4):849–864. https://doi.org/10.1016/j.asej.2020.04.001

Kontar, Y., Santiago-Fandino, V., & Takahashi, T. (2016). Tsunami Events and Lessons Learned. Springer. https://doi.org/10.1007/978-94-007-7269-4

M. Pagani, J. Garcia-Pelaez, R. Gee. K. Johnson, V. Poggi, R. Styron, G. Weatherill, M., Simionato, D. Viganò, L. Danciu, D. Monelli (2018). Global Earthquake Model (GEM) Seismic Hazard Map (version 2018.1-December 2018), DOI:10.13117/GEM-GLOBAL-SEISMIC-HAZARD-MAP-2018.1 (CC BY-NC-SA). https://maps.openquake.org/map/global-seismic-hazard-map/#2/24.7/-18.6

Ministerio de Fomento (2009). Norma de Construcción Sismorresistente: Parte general y edificación (NCSE-02). Gobierno de España. https://www.mitma.gob.es/recursos_mfom/0820200.pdf

NSR-10 (2010) Reglamento Colombiano de Construcción Sismo Resitente. Ministerio de Ambiente, Vivienda y Desarrollo Territorial. Colombia. https://www.culturarecreacionydeporte.gov.co/sites/default/files/reglamento_construccion_sismo_resistente.pdf

NTC (2018). Aggiornamento delle "Norme tecniche per le construzioni". Ministero delle infrastrutture e dei transporti. https://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

NTCDS (2020). Normas Técnicas Complementarias para Diseño por Sismo con Comentarios. NTCDS. Gaceta Oficial de la Ciudad de México. June. https://www.isc.cdmx.gob.mx/storage/app/uploads/public/5f3/59d/737/5f359d737cd93293636625.pdf

NZSEE (2017) The Seismic Assessment of Existing Buildings. Technical Guidelines for Engineering Assessments.

Ordaz (2014) Ordaz, M. G., Cardona, O. D., Salgado-Gálvez, M. A., Bernal-Granados, G. A., Singh, S. K., & Zuloaga-Romero, D. (2014). Probabilistic seismic hazard assessment at global level. International jou52219rnal of disaster risk reduction, 10, 419-427.

Orfeus Foundation (2021). European Station Book. http://orfeus-eu.org/stationbook/

RESNOM (2021). Red Sísmica del Noroeste de México. https://resnom-mf.cicese.mx/

SASMEX (2021). Boletín del Ssitema de Alerta Sísmica Mexicano (SASMEX) 7 de septiembre de 2017. http://www.cires.org.mx/sasmex_historico_ac_n.php?fecha_aviso=2017-09-07&hora_aviso=23:50:32&registros_aviso=&fecha_sismo=2017-09-08&hora_sismo=04:49:17&latitud_sismo=14.76&longitud_sismo=-94.10&profundidad_sismo=45.00&magnitud_sismo=8.2&redes_sismo=SASMEX

SIA (2003). SIA 261 – Actions on structures. Zurich: The Swiss Society of engineers and architects

Suárez, G., Espinosa‐Aranda, J. M., Cuéllar, A., Ibarrola, G., García, A., Zavala, M., ... & Islas, R. (2018). A dedicated seismic early warning network: The Mexican Seismic Alert System (SASMEX). Seismological Research Letters, 89(2A), 382-391.

SSN (2021). Redes Sismológicas. Servicio Sismológico nacional. Mexico. Accessed 04 september 2021

Suárez, G., van Eck, T., Giardini, D., Ahern, T., Butler, R., & Tsuboi, S. (2008). The international federation of digital seismograph networks (FDSN): An integrated system of seismological observatories. IEEE Systems Journal, 2(3), 431-438. https://doi.org/10.1109/JSYST.2008.2003294

Tatehata H. (1997) The New Tsunami Warning System of the Japan Meteorological Agency. In: Hebenstreit G. (eds) Perspectives on Tsunami Hazard Reduction. Advances in Natural and Technological Hazards Research, vol 9. Springer, Dordrecht. https://doi.org/10.1007/978-94-015-8859-1_12

V Silva, D Amo-Oduro, A Calderon, J Dabbeek, V Despotaki, L Martins, A Rao, M Simionato, D Viganò, C Yepes, A Acevedo, N Horspool, H Crowley, K Jaiswal, M Journeay, M Pittore (2018). Global Earthquake Model (GEM) Seismic Risk Map (version 2018.1). DOI: 10.13117/GEM-GLOBAL-SEISMIC-RISK-MAP-2018.1