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Deliverable No: D2.1

WP2. A framework for seismic hazard assessment in the Greece-Turkiye CBA

Task T2.1 A framework for information exchange for seismic hazard harmonization

DELIVERABLE COORDINATED BY:

INSTITUTE OF ENGINEERING SEISMOLOGY & EARTHQUAKE ENGIN. - EARTHQUAKE PLANNING AND PROTECTION ORGANIZATION (ITSAK/EPPO)

INVOLVED PARTNERS:

DIETHNES PANEPISTIMIO ELLADOS (IHU)

ICISLERI BAKANLIGI AFET VE ACIL DURUM YONETIMI BASKANLIGI (AFAD)

GEBZE TEKNIK UNIVERSITESI (GTU)

PROJECT DETAILS

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DELIVERABLE CONTRIBUTORS

ITSAK/EPPO: Theodoulidis N., Margaris B., Sotiriadis D., Grendas I.

IHU: Papatheodorou K., Evangelidis K., Konstantinidis A., Scordilis E.

AFAD: Nurlu M., Sezer S., Kuterdem K., Türkoğlu M., Özsaraç V,

GTU: Zülfikar C., Okuyan S.

DOCUMENT RELEASE SHEET

Deliverable Responsible Partner: PARTNER ACRONYM (e.g. IHU)		
Approval	Konstantinos Papatheodorou (IHU)	Signature 30.11.2023
Approval	Can Zülfikar (GTU)	Signature 30.11.2023
Approval	Murat Nurlu (AFAD)	Signature 30.11.2023
Approval	Nikolaos Theodoulidis (ITSAK/OASP)	Signature 30.11.2023
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RECORD OF REVISIONS

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1 BACKGROUND OF THE DOCUMENT

1.1 RELATED WORKPACKAGE AND TASKS

This document describes the activities that took place in the framework of the WP2: A framework for seismic hazard assessment in the Greece-Tuïrkiye CBA and is related to the Task Task T2.1: A framework for information exchange for seismic hazard harmonization.

This project Activity relates to definition of a harmonized framework towards seismic hazard assessment in the Greece-Tuïrkiye Cross Border Area (CBA). More specifically, in this Activity information and all necessary information/input parameters will be discussed and decided jointly among all four Partners to assureharmonization of seismic hazard in the Greece-Turkiye CBA

1.2 SCOPE AND OBJECTIVES

The scope of this document is to outline the activities carried out within the framework of Task 2.1 aimed at accomplishing the project objectives. These efforts are ultimately geared towards attaining the Specific Objective of "Seismic Hazard Assessments" as stipulated by the funding Programme under the Call "Prevention and Preparedness Projects on Civil Protection and Marine Pollution (UCPM-2022-PP)." In pursuit of this goal, the present deliverable places emphasis on the following project objectives:

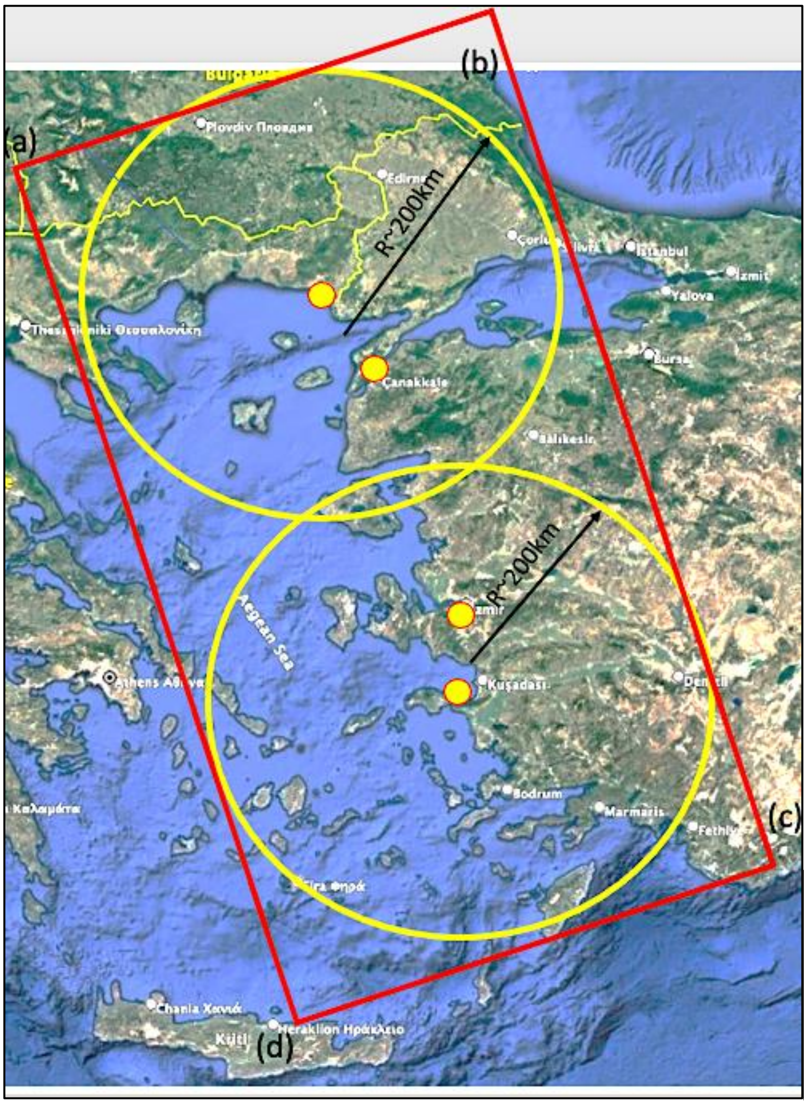
- Harmonizing procedures for seismic hazard assessment in areas of high seismicity within the Greek & Turkiye Cross Border Area (CBA).
- Establishing collaborative data and information sharing through a Rapid Earthquake Damage Assessment (REDA) platform.
- Leveraging the outcomes of the EU-funded project REDACt (https://www.redact-project.eu/) and employing a shared tool/system for the collaborative processing and sharing of data and information (with potential modifications or additions as required).

Consequently, this document presents a framework of input parameters and information exchange for seismic hazard assessment in the Greece-Turkiye Cross Border Area in a harmonized way. This Deliverable will ensure all required harmonization steps towards seismic hazard assessment in the CBA.

2 FRAMEWORK FOR SEISMIC HAZARD ASSESSMENT PROBABILISTIC SEISMIC HAZARD ASSESSMENT IN THE GREECE-TURKIYE CBA

2.1 CROSS BORDER AREA AND PILOT IMPLEMENTAION SITES

After internal meetings & discussions between the Greek and Turkish partners contributing to this Deliverable, it was decided that the Cross Border Area(CBA) will be defined based on the faur selected Pilot Implementation Sites (PIS), namely Alejandroupoli-Canakale and Samos-Izmir. Based on this prerequisite and taking into account a distance up to which seismic ground motion is capable of generating strong ground motion (say with PGA greater of about 1%g), a preliminary rectangular area has been delineated as is shown in Figure 1.



(a) 41.826N 22.894E,
(b) 42.593N 27.677E,
(c) 36.373N 29.903E,
(d) 35.336N 25.322E,
(a) 41.826N 22.894E.

Figure 1. Greece-Turkiye Cross Border Area around the Pilot Implementation Sites of the EReS project.

In ordert o prepare the catalogue to be used in Seismic Hazard Assessment in the CBA the following steps are proposed.

The test-sites of the project are four cities in the common border area (CBA) between Greece and Turkyie, namely Alexandroupoli, Canakkale, Izmir and Vathy (Samos). By considering circular areas of radius R=200km centered on each of these cities, a wide region is defined. To avoid any phenomena of edge-effects we expanded this region creating a frame bounded by the coordinates 22.5-30.5^{o}E and 35.0-43.0^{o}N within which the focal parameters of all available earthquakes expanding over a wide period will be collected (red dashed line in Figure 2). In this way, an earthquake catalog will be formed to be used for the seismic hazard study.

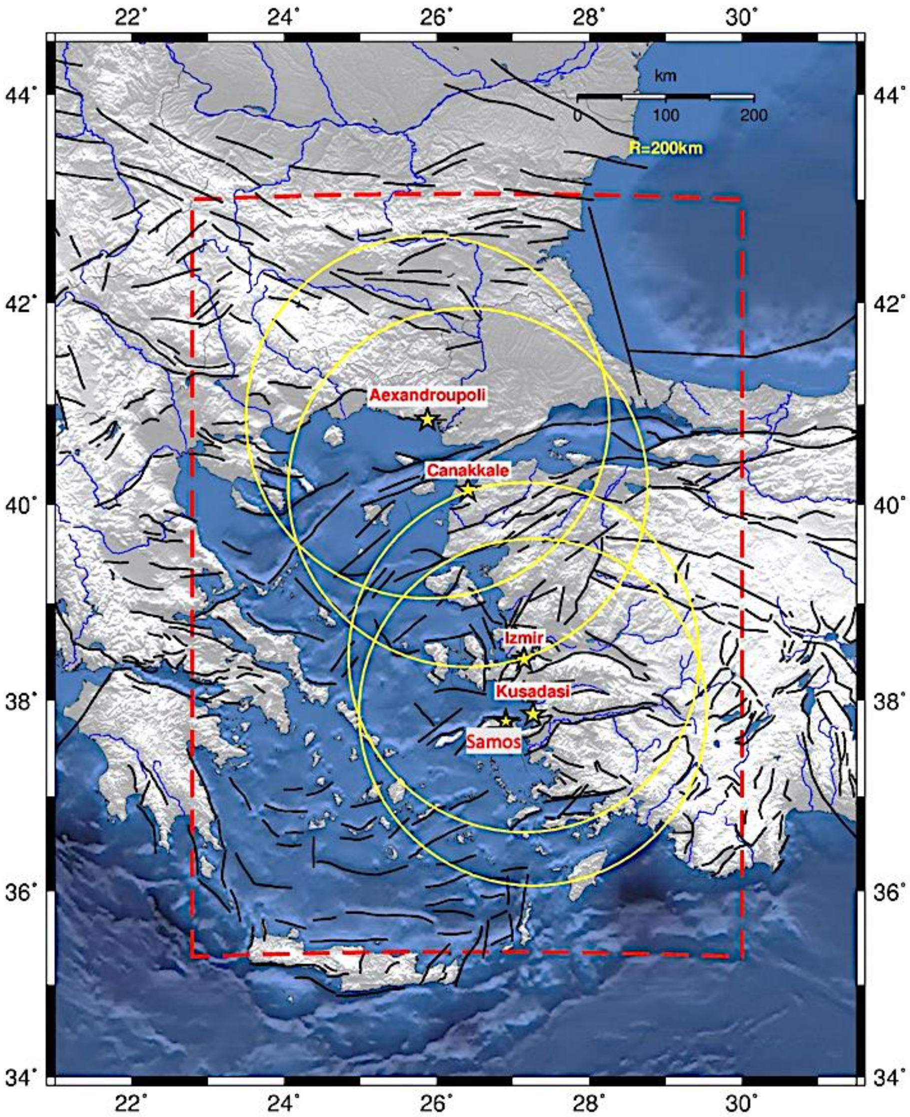


Figure 2. Region to be covered by the final catalog (red dashed line). Yellow circles delimit circular areas of R=200km centered on each Pilot Implementation Site.

2.2. INPUT PARAMETERS FOR PROBABILISTIC SEISMIC HAZARD ASSESSMENT

The following four (4) steps **(A) to (E)** are decided to be examined with respect to exchange of information and input parameters in the harmonization framework.

(A) Seismic Catalogue, seismic sources, and faults

The seismicity catalog to be formed mentioned above, must satisfy the following requirements:

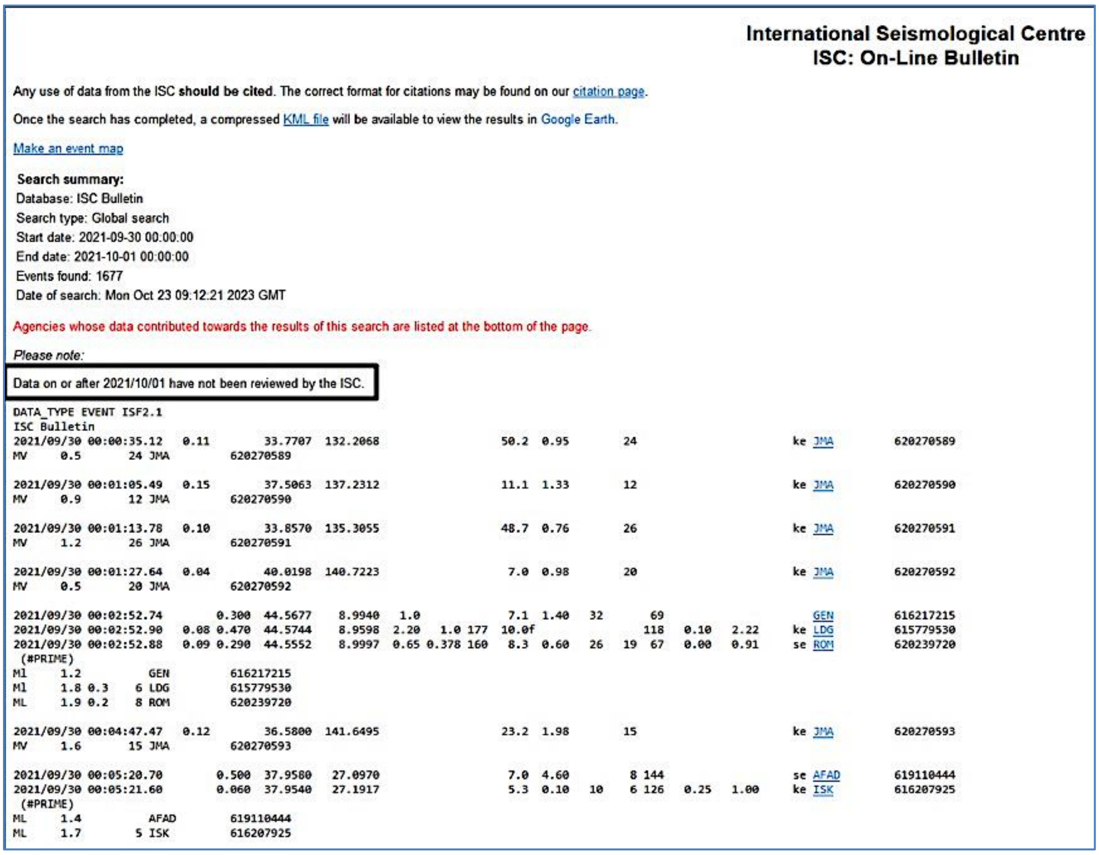
1) It must span a long period of time in to be as representative as possible of the background seismicity of the area
3) The focal parameters of the earthquakes of the catalog must be estimated uniformly to assure homogeneity.
4) All the magnitudes must be expressed in one, unique, reliable, and widely used magnitude scale.

In addition, the earthquake catalogue data sources can be compiled as follows. There are many data sources that could be used to accomplish this task (e.g. bulletins or catalogs of regional centers and networks):

- ISC bulletins (http://www.isc.ac.uk/iscbulletin/)
- Papazachos and Papazachou, (1997)
- Papazachos and Papazachou, (2003)
- Karnik, (1996)
- Engdahl and Villaseñor (2002)
- Comninakis and Papazachos, (1986)
- Pacheco and Sykes, (1992)
- Ambraseys, (2009)
- Gutenberg and Richter (1954, 1956)
- Bulletins of AUTh
- On-line catalog of NOA

To overcome the issue of different focal parameters reported for the same earthquakes by different agencies it is a good practice to adopt solutions published by the International Seismological Center, ISC (figure 2). The main reason is that for the estimation of focal parameters the ISC applies a specific, unified procedure and for this purpose uses a large amount of data collected from all cooperating regional networks.

Therefore, all focal parameters published by the ISC are homogeneously defined and, consequently, consistent with each other. The reviewed data, at the moment of writing this report, cover the period 1964-2021/09 (Figure 3).



International Seismological Centre
ISC: On-Line Bulletin

Any use of data from the ISC **should be cited**. The correct format for citations may be found on our citation page.

Once the search has completed, a compressed KML file will be available to view the results in Google Earth.

Make an event map

Search summary:
Database: ISC Bulletin
Search type: Global search
Start date: 2021-09-30 00:00:00
End date: 2021-10-01 00:00:00
Events found: 1677
Date of search: Mon Oct 23 09:12:21 2023 GMT

Agencies whose data contributed towards the results of this search are listed at the bottom of the page.

Please note:

Data on or after 2021/10/01 have not been reviewed by the ISC.

```
DATA_TYPE EVENT ISF2.1
ISC Bulletin
2021/09/30 00:00:35.12   0.11       33.7707  132.2068                      50.2  0.95        24                      ke JMA       620270589
MV     0.5       24 JMA          620270589

2021/09/30 00:01:05.49   0.15       37.5063  137.2312                      11.1  1.33        12                      ke JMA       620270590
MV     0.9       12 JMA          620270590

2021/09/30 00:01:13.78   0.10       33.8570  135.3055                      48.7  0.76        26                      ke JMA       620270591
MV     1.2       26 JMA          620270591

2021/09/30 00:01:27.64   0.04       40.0198  140.7223                       7.0  0.98        20                      ke JMA       620270592
MV     0.5       20 JMA          620270592

2021/09/30 00:02:52.74        0.300  44.5677    8.9940   1.0                7.1  1.40   32       69                       GEN       616217215
2021/09/30 00:02:52.90   0.08 0.470  44.5744    8.9598  2.20    1.0 177 10.0f                  118   0.10    2.22   ke LDG       615779530
2021/09/30 00:02:52.88   0.09 0.290  44.5552    8.9997  0.65 0.378 160   8.3  0.60   26   19  67   0.00    0.91   se ROM       620239720
 (#PRIME)
Ml     1.2          GEN          616217215
Ml     1.8 0.3    6 LDG          615779530
ML     1.9 0.2    8 ROM          620239720

2021/09/30 00:04:47.47   0.12       36.5800  141.6495                      23.2  1.98        15                      ke JMA       620270593
MV     1.6       15 JMA          620270593

2021/09/30 00:05:20.70        0.500  37.9580   27.0970                      7.0  4.60         8 144                  se AFAD      619110444
2021/09/30 00:05:21.60        0.060  37.9540   27.1917                      5.3  0.10   10    6 126   0.25    1.00   ke ISK       616207925
 (#PRIME)
ML     1.4          AFAD         619110444
ML     1.7        5 ISK          616207925
```

Figure 3. Screenshot of the output after an ISC bulletin search. It is noticed that "Data on or after 2021/10/01 have not been reviewed by the ISC".

For earthquakes that occurred before 1964, their data would be adopted from previously mentioned already published earthquake catalogs.

To ensure the magnitude homogeneity of the catalog, the moment magnitude scale must be selected as the reference one because:

- It scales linearly with seismic moment and energy for a wide magnitude range.
- It does not saturate.

All other magnitude types (available from the original sources) must be transformed into the moment magnitude scale, M_w, by appropriate formulas already published (e.g., Papazachos et al., 1997; Baba et al., 2000; Scordilis, 2005, 2006; Tsampas, 2006; Duni et al., 2010)

Therefore, for shallow and for intermediate depth earthquakes respective already defined relations will be used to convert magnitudes expressed in other scales to equivalent moment magnitudes, M_w.

The finally adopted magnitude for each earthquake of the formed catalog will be either the original moment magnitude (published by Pacheco and Sykes, 1992; GCMT and/or USGS), if available, or the ***equivalent*** moment magnitude, estimated as the ***weighted mean*** of the converted magnitudes, by weighting each participating magnitude with the inverse standard deviation of the respective calibrating relation applied. At the end of the day:

1) Events with no reported magnitudes or magnitudes with values completely out of the limits of the respective converting relations will not be included in the final catalog
2) The original sources will be cross-checked to avoid omitting significant events (typically of $M \geq 6.0$)
3) The final catalog will include the focal parameters of all known earthquakes within the frame 22.5-30.5ºE and 35.0-43.0ºN, which are reported by at least one of the above-mentioned sources and for which moment magnitudes (original or converted) could be assessed.

For the quality control of the catalog, the following steps must be taken:

- Its completeness, in respect to magnitudes, must be checked as well as its variation with time and in space.
- For each period of completeness (considering the respective cut-off magnitude) maps showing the spatial distribution of seismicity parameters (e.g. b-value, a1/b value, etc.) must be prepared.
- The spatial distribution of these values may be tested against the values of respective seismicity parameters defined in previous seismic zonation studies, to check if and how the outcome of these studies better fits to our data.

Regarding the seismic sources and faults in the CBA, the backbone of the European Seismic Hazard Model input will be utilized and updated where possible and if new information is available to the project Partners.

(B) Ground Motion Models (GMMs ή GMPEs)

All recently available Ground Motions Prediction Equations (GMPEs) or Ground Motion Models (GMMs) based on data from seismotectonic environment similar to the one of the broader CBA, will be compiled for the project needs, both for shallow crustal and subduction earthquakes. The most suitable GMMs for the CBA will be selected after appropriately ranking them. Their weights in the seismic hazard analyses will be also based upon the ranking procedure.

(C) Logic Tree Proposition

An important step in seismic hazard assessment is modeling the epistemic uncertainty associated to the seismic source models, the maximum earthquake magnitude and the ground motion models. This will be achieved through a comprehensive logic-tree approach, which has been used widely in the literature (Bommer and Scherbaum, 2008; Woessner et al., 2015; Danciu et al., 2021). The seismic hazard model for the CBA will be jointly decided and will be based on three main branching levels, namely (1) the seismic source models, (2) the maximum magnitude and (3) the ground motion models (i.e., GMPEs). A schematic illustration of the full logic-tree is shown in Figure 4.

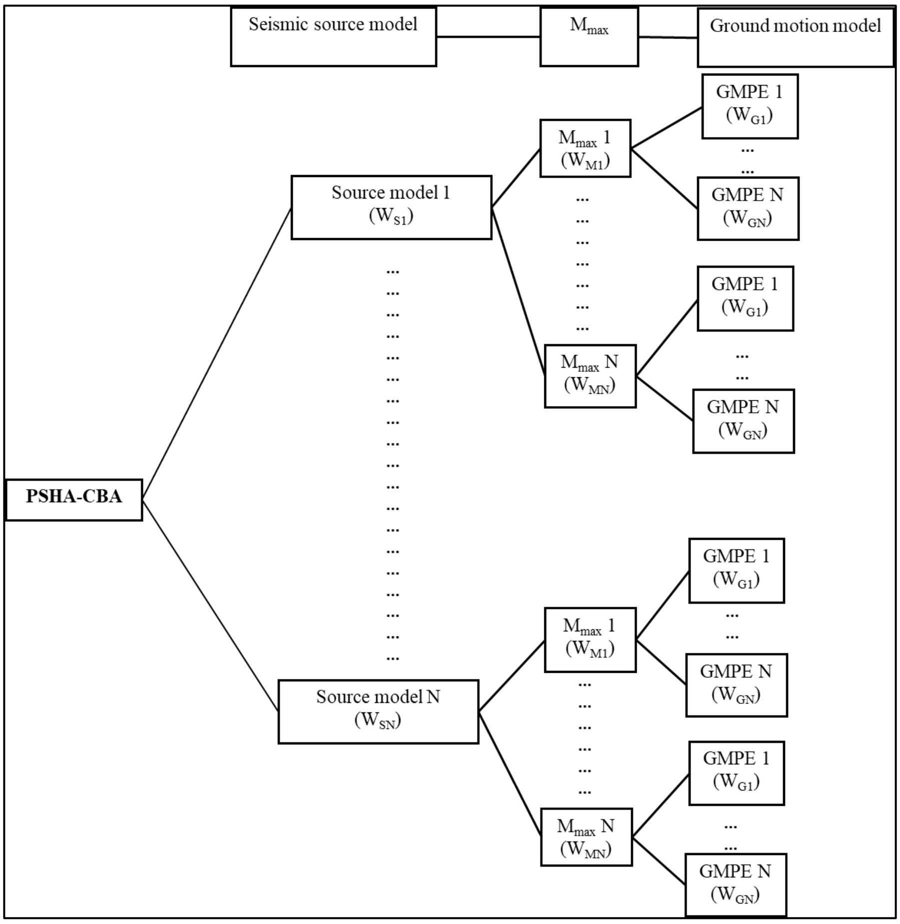


Figure 4. Schematic illustration of logic-tree which will be implemented for the Probabilistic Seismic Hazard Assessment of the CBA.

The relevant weights for the seismic source models (W_{Si}), the maximum earthquake magnitude (W_{Mi}) and the ground motion models (W_{Gi}) will be jointly decided upon the selection of the individual logic-tree components and will be based on data-driven evaluation and/or expert judgment.

(D) Software Selection for Probabilistic Seismic Hazard Analyses(PSHA)

The software which will be used to conduct the PSHA analyses for the CBA should follow current standards in software development, such as test-driven development and continuous integration of recent advances in seismic hazard assessment. Moreover, an appropriate level of confidence in its implementation should exist, through its reference on published research projects.

Having in mind all the above, the software OpenQuake (Pagani et al., 2014) is jointly proposed to perform the require PSHA analyses for the CBA. Openquake-engine is the seismic hazard and risk calculation software developed by the GEM Foundation. It is open-source and community-driven and has been widely used for PSHA analyses worldwide (Woessner et al., 2015; Şeşetyan et al., 2019; Poggi et al. 2020; Danciu et al., 2021; Rahman et al., 2021; Sotiriadis et al., 2023). OpenQuake-engine is capable of modeling a wide variety of seismic source typologies as well as magnitude-frequency distributions and magnitude-scaling expressions. It also includes a large library of pre-defined GMPEs, whereas its versatile architecture allows implementing new ones based on python-based scripts.

(E) Presentation of Results of Probabilistic Seismic Hazard Assessment (PSHA)

The results of the PSHA will be on “rock” conditions, for mean return periods T=100, 475, 950yrs and for intensity measures PGA, PGV, PSA(T=0.3sec, 0.6sec, 1.0sec) must be provided in respective Maps and Tables for an optimized grid of points, around the Pilot Implementation Areas of the CBA.

2.3 INPUT PARAMETERS FOR DETERMINISTIC SEISMIC HAZARD ASSESSMENT (SHAKEMAPS)

In this section of the Deliverable a short description and rationale selection of respective input parameters in Skakemaps, both for scenario and real time seismic hazard assessment) is presented.

To this aim, seismic faults around the Pilot Implementation Sites (PIS), that is, Alexandroupoli – Canakale and Samos - Izmir), as shown in Fig. 1, will be used. More specifically, at least three (3) scenarios of earthquakes will be assumed; (i) for near-field (R<20km), (ii) for intermediate-field (20<R<50km) and (iii) for far-field (R>50km).

Regarding the GMPEs, the same as in probabilistic seismic hazard assessment will be used. As soil geologic layers amplification, the Vs30 proxy on regional for the CBA and local scale for the PIS will be utilized. A scenario of the Samos

Oct. 30, 2020 earthquake (M7.0) using the REWDAS software is presented in Fig. 5.

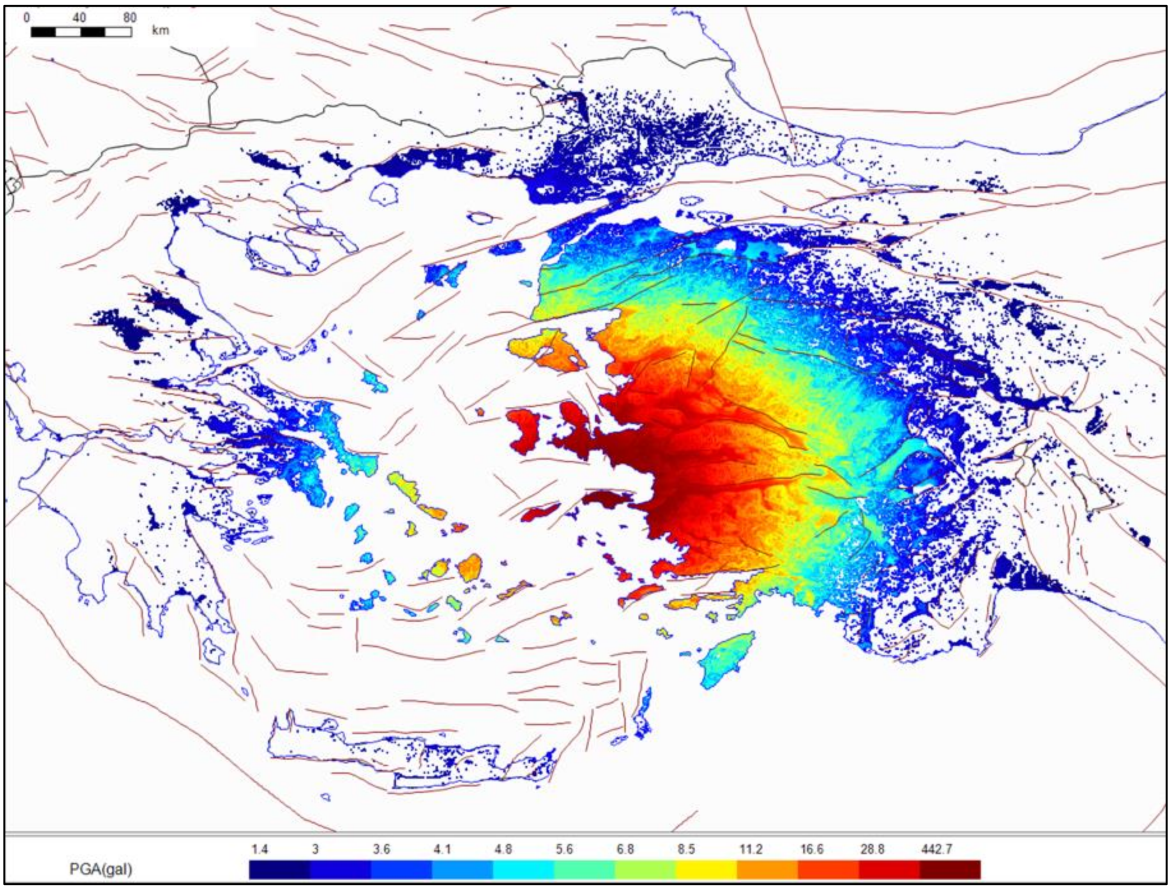


Figure 5. Shakemap scenario (PGA in cm/s^2 distribution) for the Samos Oct. 30,2020 earthquake (M7.0) based on the REDA System s/w(https://www.redact-project.eu).

Regarding the real time Shakemaps generation, all appropriate parametrizations of the REDA System will be jointly applied and checked, to feed the REDA Systen for Rapid Earthquake Damage Assessment of the selected school buildings in the Pilot Implementation Sites (Alexandroupoli – Canakale and Samos - Izmir).

The ground motion intensity will be provided in PGA, PGV, and PSA values for selected natural periods (T=0.3sec, 0.6sec, 1.0sec).

References

Ambraseys, N. (2009). Earthquakes in the Mediterranean and Middle East. *Cambridge University Press*, ISBN 9780521872928, 947pp.

Baba, A.B., Papadimitriou, E.E., Papazachos, B.C., Ch.A. Papaioannou and B.G. Karakostas, 2000. Unified local magnitude scale for earthquakes of south Balkan area. *Pure Appl. Geophys.*, 157, 765-783

Bommer JJ, Scherbaum F (2008). The use and misuse of logic trees in probabilistic seismic hazard analysis. Earthquake Spectra, 24:997–1009. doi:10.1193/1.2977755.

Comninakis, P.E. and Papazachos, B.C., 1986. A catalogue of earthquakes in Greece and surrounding area for the period 1901-1985. *Publ. Lab., Univ. of Thessaloniki*, 1, 167 pp.,

Danciu, L., Nandan, S., Reyes, C., Basili, R., Weatherill, G., Beauval, C., Rovida, A., Vilanova, S., Sesetyan, K., Bard, P.-Y., et al. (2021). The 2020 update of the European Seismic Hazard Model: Model Overview, EFEHR Technical Report 001, v1.0.0; ETH Zürich: Zürich, Switzerland, 2021.

Duni, L., Sh. Kuka and N. Kuka, 2010. Local relations for converting M_L to M_W in southern-western Balkan region. *Acta Geod. Geoph. Hung.*, 45(3), 317–323

Engdahl, E. R., and A. Villaseñor (2002). Global seismicity: 1900–1999. In *International Handbook of Earthquake and Engineering Seismology, Part A*, ed. W. H. K. Lee, H. Kanamori, P. C. Jennings, and C. Kisslinger, 665–690. Boston: Academic Press.

Gutenberg, B. and C.F. Richter (1954). Seismicity of the Earth and Associated Phenomena, *Princeton University Press*, Princeton.

Gutenberg, B. and Richter, C.F. (1956). Magnitude and energy of earthquakes, *Ann. Geofis*. 9, 1–15.

Karnik, V. (1996). Seismicity of Europe and the Mediterranean. In: Klima, K. (ed.), *Academy of Sciences of the Czech Republic*, Geophysical Institute, 28 pp. plus earthquake catalogue

Pacheco, J.F., Sykes, L.R., 1992, Seismic moment catalog of large shallow earthquakes, 1900 to 1989. *Bull Seism Soc Am* 82:1306-1349

Papazachos B. and C. Papazachou, (1997). The earthquakes of Greece, *Ziti publications*, ISBN 960-431-416-5, 304pp.

Papazachos, B.C. and Papazachou, C.B., 2003. The earthquakes of Greece, *Ziti Publications*, Thessaloniki, 273pp (in Greek).

Papazachos, B.C., Kiratzi, A.A. and Karakostas, B.G., 1997. Toward a homogeneous moment-magnitude determination for earthquakes in Greece and surrounding area, *Bull. Seism. Soc. Am.*, 87, 474-483.

Poggi, V., Garcia-Peláez, J., Styron, R. et al. (2020). A probabilistic seismic hazard model for North Africa. Bulletin of Earthquake Engineering 18, 2917–2951. https://doi.org/10.1007/s10518-020-00820-4

Rahman, A.u., Najam, F.A., Zaman, S. et al. (2021). An updated probabilistic seismic hazard assessment (PSHA) for Pakistan. Bulletin of Earthquake Engineering 19, 1625–1662. https://doi.org/10.1007/s10518-021-01054-8

Scordilis, E. M. (2006). Empirical global relations converting M_s and m_b to moment magnitude, *Journal of Seismology* **10**, 225-236.

Scordilis, E.M., 2005. Globally valid relations converting Ms, mb and M_{JMA} to Mw. *NATO Advanced Research Workshop on Earthquake Monitoring and Seismic Hazard*

Mitigation in Balkan Countries, 11-17 September 2005, the Rila Mountains-Resort Village Borovetz, Bulgaria, Abstracts book, 158-161

Şeşetyan, K., Demircioğlu Tümsa, M. B., & Akinci, A. (2019). Evaluation of The Seismic Hazard in The Marmara Region (Turkey) Based on Updated Databases. *Geosciences*, *9*(12), 489. https://doi.org/10.3390/geosciences9120489

Sotiriadis, D., Margaris, B., Klimis, N., & Dokas, I. M. (2023). Seismic Hazard in Greece: A Comparative Study for the Region of East Macedonia and Thrace. GeoHazards, 4(3), 239-266. https://doi.org/10.3390/geohazards4030014

Tsampas, A.D., E.M. Scordilis, C.B. Papazachos and G.F. Karakaisis. Global magnitude scaling relations for intermediate-depth and deep-focus earthquakes, *Bull. Seism. Soc. Am.*, doi: 10.1785/0120150201, 106, 2, 418–434, 2016.

Woessner, J., Danciu, L., Giardini, D., Crowley, H., Cotton, F., Grünthal, G., Valensise, G., Arvidson, R., Basili, R., Demircioglu, B., et al. (2015). The 2013 European Seismic Hazard Model: Key components and results. Bulletin of Earthquake Engineering, 13, 553–3596.