RESORCE : une base de données de mouvements sismiques

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RÉSUMÉ. *Pour dériver et tester des modèles de mouvement sismique et pour toutes les applications d'aléa sismique et d'ingénierie parasismique, disposer d'une base de données de mouvements sismiques de haute qualité est un élément essentiel. C'est dans cette optique qu'une base de données accélérométrique à l'échelle pan-européenne a été développée. RESORCE (REference databaSe fOR seismiC ground motion in Europe) a été développée dans le cadre du programme de recherche & développement SIGMA avec les caractéristiques suivantes :*

- Traitement homogène des enregistrements
- Uniformité de format des informations disponibles associées aux enregistrements (méta-paramètres)
- Estimation des incertitudes associées aux paramètres principaux (magnitude, distance, vs30)
- Portail internet d'accès aux données permettant des requêtes en fonction de différents paramètres (www.resorce-portal.eu),
- Qualité: la base de données contient seulement des données et informations vérifiées et validées
- Base de données issue par versions successives. Une fois publiée, chaque version reste « figée » et accessible

ABSTRACT. *With the aim of improving seismic ground-motion models and reducing associated uncertainties, the compilation of a high-quality database of seismic-motion recordings and associated meta-parameters is of primary importance. SIGMA research and development project, devoted to the improvement of seismic hazard estimates, methods and data for France and nearby regions, has been funding the implementation of RESORCE (Reference databaSe fOR seismiC round-motion in Europe. RESORCE is meant to be an up-to-date, homogeneous, integrated European seismic-motion database for developing and testing ground-motion models used in engineering seismology and for earthquake engineering purposes. It only contains validated data and it is released through successive versions. Each version of RESORCE keeps frozen over time and at any time it is possible to go back to a given version using the internet portal (www.resorce-portal.eu). Uncertainties associated to main meta-data (magnitude, distance, vs30) are provided as well.*

MOTS-CLÉS : *base de données, mouvements sismiques, accélérométrie, aléa sismique, paramètres sismologiques.*

KEYWORDS: *database, ground motion, accelerograms, seismic hazard, seismic metadata.*

1. Introduction

The idea of implementing RESORCE (REference databaSe fOR seismiC ground-motion in Europe), devoted to the development and testing of ground-motion models to be used for seismic hazard studies and other engineering seismology and earthquake engineering purposes, emerged from the need of having a single integrated database for Europe, constructed with high standards and containing only verified data. Indeed the quality, completeness and level of information associated to data are highly heterogeneous among the different seismological networks and agencies in Europe. On top of this, ground motion developers use their own data and meta-data processing procedures, which increases the epistemic uncertainties associated to ground-motion models.

In the past, the most successful attempt to gather strong-motion data in and around Europe was led by Prof. Ambraseys and the Engineering Seismology and Earthquake Engineering section of Imperial College

London, through FP4 and FP5 (and earlier) projects. The group collected, compiled and processed the accelerometric data through collaborations with seismic agencies since 1971. The products of this endeavor are a CD-ROM released in 2004 (Ambraseys et al., 2004b) and the ISESD website (Internet Site for European Strong-motion Data, Ambraseys et al., 2004a), which disseminates the available pan-European strong-motion recordings assembled up until that date. The metadata information, as well as the data processing of strong-motion recordings disseminated in these sources was roughly uniform. Several ground-motions models (e.g. Ambraseys et al., 2005, Berge-Thierry et al., 2003) benefited from this database. This attempt became silent after 2004 because of lack of financial support, inadequate manpower as well as the limited involvement of seismic agencies providing data to this initiative.

After this initiative, the European Commission funded various projects within the context of the 6th and 7th Framework Programs (FP6 and FP7, projects NERIES and NERA). None of these projects aimed to deliver an up-dated version of the pan-European strong-motion database. During the past decade, seismically-active countries like Turkey and Italy improved their strong-motion databases through national projects. These projects implemented their own procedures while assembling the databases, which may result in a lack of uniformity in metadata compilation and record processing when integrated in a single strong-motion databank. The recently closed SHARE (Woessner et al., 2015) project gathered data from recent strong-motion databanks but no attempt was made to homogenize the data processing of the accelerograms nor to improve the earthquake and station metadata. The recordings from recent earthquakes of engineering significance in the broader European region (e.g., 2009 L'Aquila Earthquake Mw 6.3; 2011 Van Earthquake Mw 7.1; 2011 Van-Edremit Earthquake Mw 5.6; 2011 Kütahya-Simav Earthquake Mw 5.9; 2010 Elazıg Kovancılar Earthquake Mw 6.1) are either entirely or mostly disregarded in the SHARE strong-motion databank.

In this context, the primary motivation behind RESORCE is to be a single integrated accelerometric databank for the broader European area. The uniform processing of accelerometric records, as well as the improvement of meta-data estimates (particularly magnitudes and distances) are other key points of RESORCE. Indeed, the information collected by recent projects and provided in literature are used to provide the best information available. A peculiarity of RESORCE is to be implemented through successive versions. Each version is frozen over time and keeps accessible at any time through the internet portal. This guarantees transparency and traceability of ground-motion models developed from a given version of RESORCE.

2. RESORCE – 2013 : content and improvements

The starting point of RESORCE is the pan-European sub-set of the SHARE strong-motion databank (Yenier et al., 2010). The initial version of RESORCE was published in 2012 (Akkar et al., 2014). This version mainly includes ISESD database records, as well as Italian and Turkish data collected by national databases (ITACA, Luzi et al., 2010 and T-NSMP, Akkar et al., 2010, Sandikkaya et al., 2010). Recordings from other parts of Europe and the Middle East were quite limited.

A new version of RESORCE was released in 2013. This version upgrades the data content by including accelerograms from Greece, Switzerland and France. The additional Greek accelerograms were retrieved from the HEAD (HEllenic Accelerometric Data; http://www.itsak.gr/en/db/data) database. The French accelerograms were incorporated from RAP (French Acceleremoteric Network; http://www-rap.obs.ujf-grenoble.fr) whereas the Swiss data were compiled from the Swiss Seismic Network (SED; www.seismo.ethz.ch). The latter two national datasets mainly consist of low-to-moderate magnitude accelerograms increasing the magnitude coverage of RESORCE towards lower magnitude events. Additional data from France and Switzerland enable better representation of low-seismicity regions in Europe by RESORCE. Figure 1 shows the RESORCE earthquake locations map.

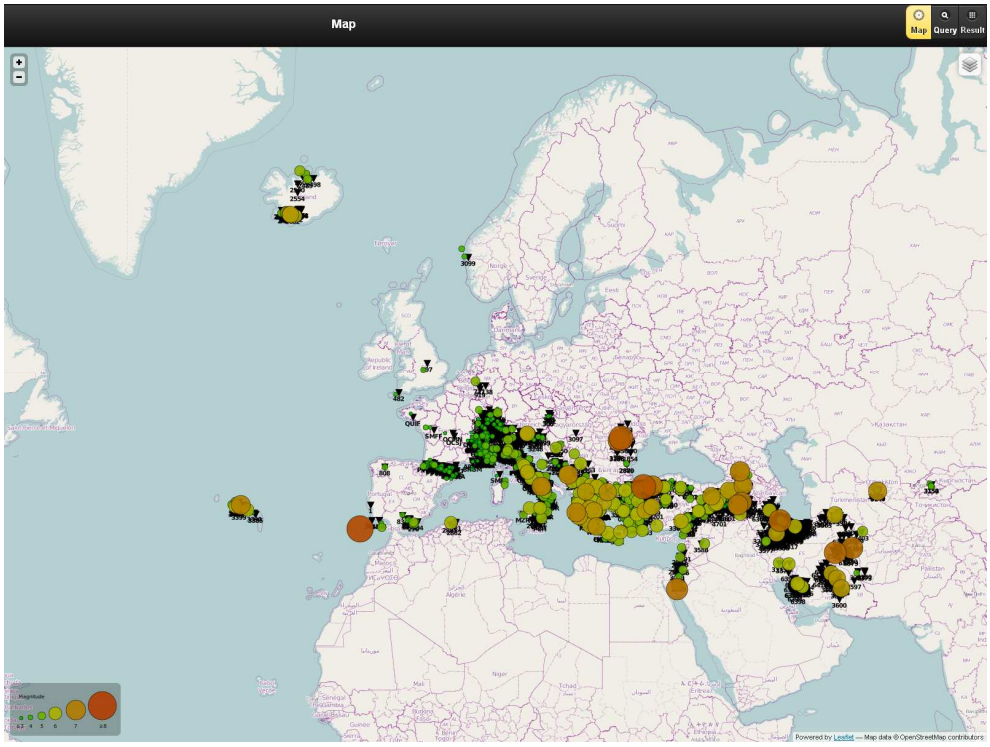

Figure 1. *RESORCE earthquakes location map (from http://www.resorce-portal.eu)*

A third version of RESORCE (planned for the end of 2015) will include the continuous improvement of meta-data associated to records (as the site characterization of some French stations), as well as an estimate of uncertainties associated to metadata, in particular magnitude, distances and vs30. On the other hand this 2015 version will not update the data content through the integration of new data.

2.1. Overall procedure for the integration of accelerometric data

The general procedure to integrate accelerometric data in RESORCE – 2012 was described by Akkar et al. (2014). In the 2013 version, a new strategy of data integration in five steps is implemented.

1. Identification of duplicated recordings, stations and earthquakes. The existence of duplicated events is studied by considering RESORCE – 2012. For duplicated events, the earthquake metadata information of RESORCE – 2012 is preferred to other sources as we gave a careful consideration to the event information during its compilation. To this end, we only update the station and site information of duplicated entries for the newly added data.

2. Event metadata compilation of non-duplicated earthquakes. The event metadata of new data is gathered from peer-reviewed literature as well as global, regional and local seismological agencies.

3. Compilation of station and site information. The information that is directly gathered from the Greek, Swiss and French databases is used while compiling the station information. Not all the new entries contain the complete site and station information (e.g., instrument shelter and VS30). Thus, additional site-specific studies are necessary to complete the missing station metadata for the newly added databases.

4. Calculation of source-to-site distance metrics. Repi, Rhyp, RJB and Rrup are calculated. The calculations of extended-source distance metrics (RJB and Rrup) are limited for the newly added data as most of the events do not have fault-plane solutions due to their small sizes. The extended-source

distances are computed when fault-plane solutions exist. The extended source metrics are calculated using the procedure described in Kaklamanos et al. (2011).

5. Ground-motion data processing. The data processing scheme implemented is described in Akkar et al. (2014). It is based on visual screening and band-pass filtering of raw accelerograms aimed to detect and remove non-standard errors (Douglas, 2003; Bommer and Douglas, 2004). Band-pass filtering is implemented either on records free of non-standard errors or on corrected records. Very low quality recordings are removed from the database. The band-pass filter cut-off frequencies are selected by studying the Fourier acceleration spectrum (FAS) of each raw accelerogram to detect the physically unjustifiable frequency content at high- and low-frequency components of the ground motion. 4-pole Butterworth a-causal filtering is applied in the frequency domain and the post processing procedure described in Boore et al. (2012) is used to remove the additionally introduced zero pads during band-pass filtering. The entire Band-pass filtering and post-processing scheme is described in Boore et al., 2012 and Akkar et al., 2014).

2.2. Removal of low quality data from RESORCE

The total number of multi-component accelerograms in RESORCE is 7622. The quality of some of these accelerograms is low due to sensor limitations or large source-to-site distances. Their use for engineering and seismological studies is, hence, limited. Such low-quality waveforms are removed from RESORCE by applying two criteria:

- Remove unprocessed strong-motion recordings due to their low quality (see Akkar et al., 2014 for some exemples), and

- Remove distant (very small amplitude) recordings based on a set of magnitude-dependent filtering rules that are illustrated in figure 2.

Implementation of these criteria resulted in filtering out 1985 multi-component accelerograms. The Mw vs. Repi scatter of the removed data is shown in Figure 2. The solid line represents the distance limits applied. Records that are on the right side of the solid line are removed as they do not conform to the applied distance limits. In other words, neither their amplitudes nor their quality are sufficient for research or professional use.

2.1. Overall features of RESORCE – 2013 version

The databank consists of 5637 accelerograms from 1481 strong-motion stations and 1713 earthquakes, after removing the low-quality data as discussed in the previous section. A total of 5571 accelerograms are tri-axial recordings whereas the rest are missing either one of the horizontal components or the vertical component.

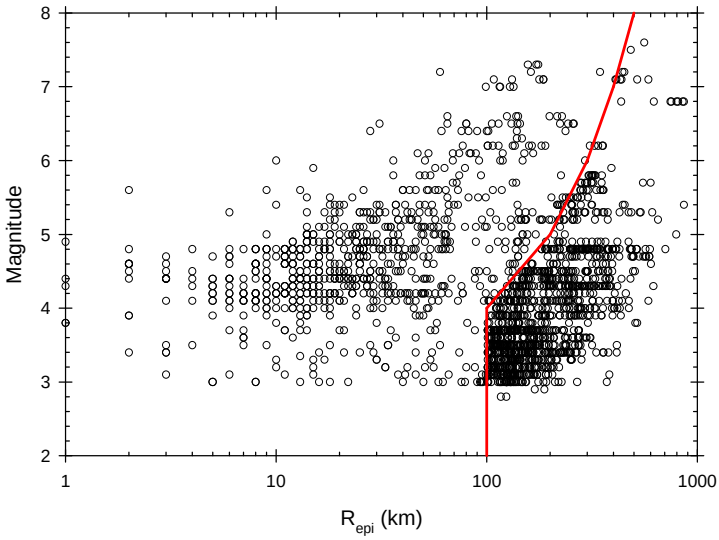

Figure 2. *Distribution of magnitude vs. distance of recordings in RESORCE. The red curve indicates the filter limit over which recordings are excluded from the database.*

Figure 3 shows the yearly distribution of the earthquakes and accelerograms in RESORCE. The strong motions archived in the databank date back to early 1970s. 60% of the earthquakes and approximately 70% of accelerograms in the databank are from earthquakes that occurred in the last 15 years (1998-2012). The higher concentration of events and records within the last 15-year time span can be attributed to the increased number of strong-motion stations all around the pan-European region. Most of the accelerograms collected in the last 15 years are recordings from digital sensors. As a matter of fact the analog and digital waveform percentages in RESORCE are 22% and 74%, respectively and almost all digital data were collected in the last decade. The remaining accelerograms do not have any sensor information.

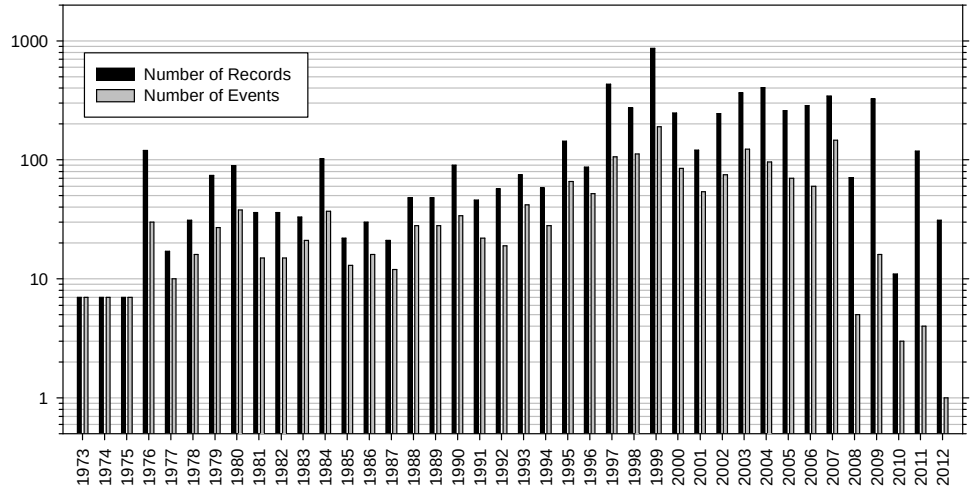

Figure 3. *Annual distribution of accelerograms and earthquakes in RESORCE (modified from Akkar et al., 2014)*

The geographical distribution and the country-based breakdown of earthquakes and stations in RESORCE (figure 1 and table 1). Almost all recorded events are shallow active crustal earthquakes and most of the accelerograms are from Turkey, Italy and Greece on the Mediterranean coast as well as from France and Switzerland in central Europe. This information emphasizes the importance of updates and expansion of metadata as well as accelerometric waveform content from these countries.

Table 1. *Country based contributions to RESORCE*

Country Name	Number of Events	Number of Records	Number of Stations	R_{epi} Range (km)	Focal Depth Range (km)	M_w Range
Albania	3	4	2	7-35	12-25	5.9
Algeria	1	3	3	29-59	10	5.9
Armenia	11	34	10	3-78	3-28	5.5-6.8
Austria	3	7	7	12-33	7-8	3.3
Bosnia and Herzegovina	5	11	9	7-19	10-15	5.7
Bulgaria	3	3	2	6-12	3-10	5.7
Croatia	5	10	7	4-168	0-39	5.5
Egypt	3	6		35-412	12-18	4.5-7.2
France	151	674	86	1-160	0-18	2.8-4.8
Georgia	11	30	9	4-181	6-19.7	4.8-7
Germany	12	65	18	4-142	4-22	3.1-5.2
Greece	297	576	123	1-370	0-127	3.1-6.9
Hungary			1	0	0	
Iceland	44	177	31	3-154	1.4-17	4.3-6.5
Iran	40	356	294	1-362	0-33	4.6-7.3
Israel	3	6	11	18-81	9-18	5.1-5.3
Italy	299	1403	350	1-279	0-255.3	3.2-6.9
Lebanon	1	1	0	75	5	5.1
Liechtenstein	1	3	1	2-5	11	3.7
Macedonia	3	9	12	12-80	15-20	5.9
Montenegro	21	58	13	1-342	5-40	5.4-6.9
Netherlands	1	3	0	58-103	14.6	5.3
Norway	2	2	1	26-78	15	5.3
Portugal	45	78	23	5-332	0-77	4.7-7.8
Romania	4	31	14	6-208	86-135.9	6.3-7.5
Serbia	7	7	1	8-21	3-10	6.3-7.5
Serbia	1	1	2	237	10	5.5
Slovenia	14	30	14	1-152	4-16	4.3-5.7
Spain	38	127	12	1-145	1.6-28	3.9-5.3
Switzerland	40	184	95	1-100	1-30	3-3.9
Syria	1	1	1	55	29	5.5
Turkey	628	1705	315	2-404	0.2-95	2.8-7.6
United Kingdom	2	2	2	35-76	8-13	2.8-7.6
Uzbekistan	13	30	12	1-53	0-45	6.8

Figure 4 shows the earthquake (left column) and accelerometric (right column) data distributions in RESORCE for moment magnitude, depth and SoF. A total of 725 events have reported moment magnitudes from international and local seismological agencies as well as earthquake-specific literature studies (first row plots). When moment magnitudes that are estimated from empirical magnitude conversion relations are included, the number of events with Mw information increases to 1234. The moment magnitudes are concentrated between

3.5 and 5.5. The total number of accelerograms having Mw information is 4430 (3486 measured and 944 converted) out of 5637.

The event and record based distributions of moment magnitude suggest the dominancy of moderate-size events ($4 \leq Mw \leq 6$) in RESORCE (61% of earthquakes and 58% of accelerograms). The fraction of events that can be considered as large earthquakes (i.e., $Mw \geq 6.5$) is only 2% of the entire population. Focal depths are less than 30km for about 92% of the events. The corresponding percentage in terms of strong-motion recordings is 98%, indicating that RESORCE is dominated by shallow crustal events. The events of depths ranging between 50 km and 140 km are mainly from the Hellenic and Cyprus Arc subduction zones, the Vrancea region, Portugal and southern Turkey.

The distribution of event and accelerometric data in terms of SoF is given in the last row of Figure 4. The majority of events and accelerograms are from strike-slip, SS, (29% of events and 30% of records) and normal, N, (22% of events and 28% of records) faults. The number of reverse, R, events and accelerograms are small when compared to the other SoF classes but they still constitute 9% of the events and 14% of the strong-motion records. The depth and SoF distributions also indicate that information is still missing (designated as "Unknown" on each histogram) for a significant portion of earthquakes in RESORCE. This lack mainly concerns the small magnitude range ($Mw \leq 5$). The major reason behind this deficiency is the lack of double-couple fault-plane solutions for small magnitude earthquakes that provide direct information for the identification of SoF and depths.

Figure 5 describes the distributions of strong-motion stations (left panel) and accelerograms (right panel) in terms of Eurocode 8 (CEN, 2004) site classification. The statistics are based on measured VS30 values and inferred site classes from local site geology. The site information of RESORCE contains a total of 419 strong-motion stations with known VS30 values thanks to site characterization studies. The corresponding number of accelerograms recorded at these stations is 2618. The number of strong-motion sites and accelerograms with site classes inferred from the local geological conditions is 632 and 2321, respectively. Of the entire accelerometric data 698 records (12% of strong-motion records in RESORCE) do not have any site characterization. The majority of accelerometric data (35%) is recorded at site class B (stiff soil) strong-motion stations. Only 2% of the accelerograms in RESORCE fall into site class D (very soft soil). The accelerograms in site class A (rock) and C (soft soil) constitute 26% and 23% of the databank, respectively.

3. Database and portal

Within the Sigma project an Internet Portal is developed to show, query and deliver Strong Motion Waveform from the database. This portal can be reached at http://www.resorce-portal.eu. RESORCE back end uses the PostgreSQL open source Database to be accessible through a Web User Interface.

RESORCE information is frozen for each version in order to let the user retrieve the same information than selected in its previous analysis. Therefore, the different versions of RESORCE are and will remain available online. Download of the full database in .csv format is also provided for each version.

The portal allows users to query the database applying filters through the "query tab". The user interface is based on the JQuery Mobile javascript library. Filters can be set upon 21 parameters:

- Event : datetime, depth, geolocalisation, magnitude, magnitude type, name, country and Fault mechanism
- Station : name, country, geolocalisation, VS30, EC8,Network and Site type
- Record : PGA,PGV, Distance Epi, Hyp, Jb and Rup

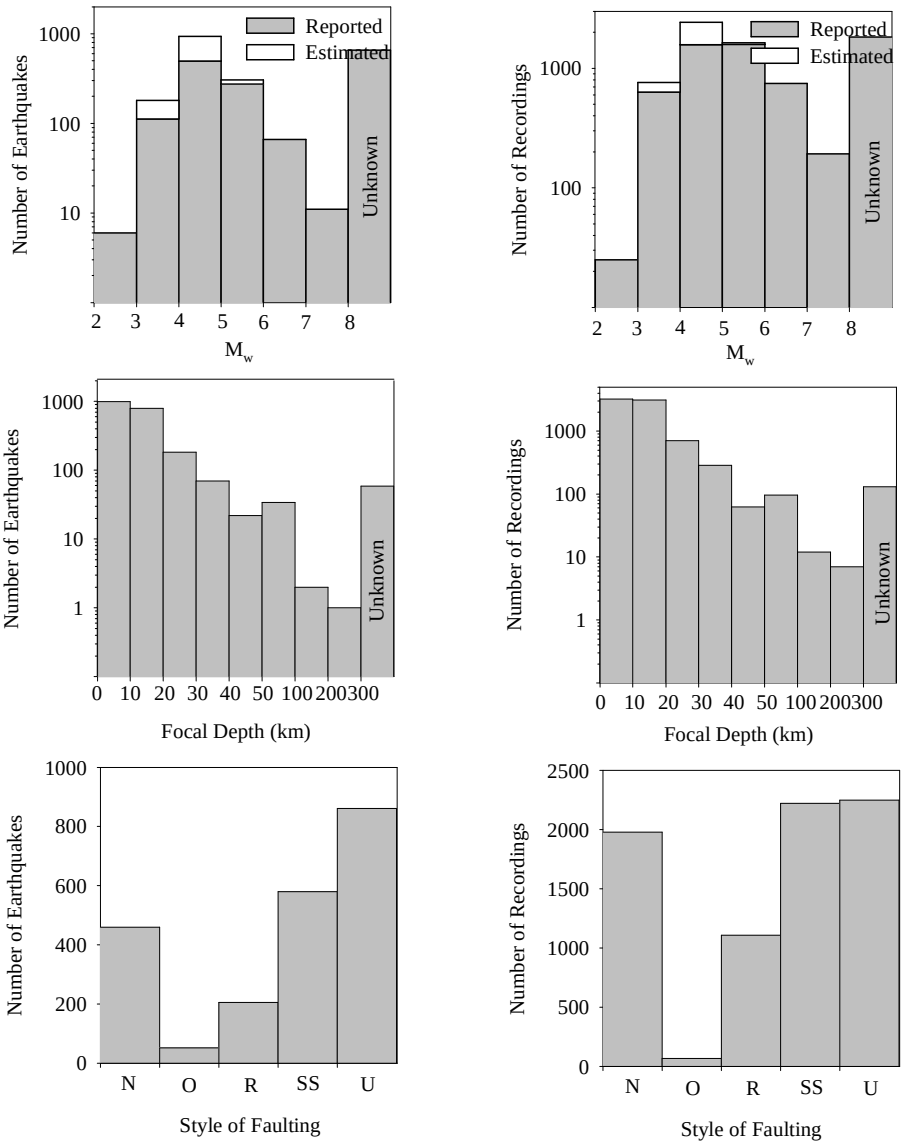

Figure 4. *Distributions of events (first column) and accelerograms (second column) in RESORCE in terms of moment magnitude (first row), depth (second row) and SoF (third row). The vertical bars labeled as "Unknown" refer to the events or accelerograms that cannot be classified within any one of these classes due to missing event information.*

The result of the request is displayed both, on a map and in the "result tab", containing details on the metadata along with waveforms and response spectra. The user can select which records should be added to a downloadable compressed file including metadata, corrected and raw data. He can click on the direct link and see the corresponding waveforms for this event on the result page. The user can also go to the results page to see all the records available for his query and select which records should be included in his selection to download. Through the RESORCE portal, external earthquake information is available on the result page by using the Unid. It includes ISC and EMSC location information for the events available in RESORCE.

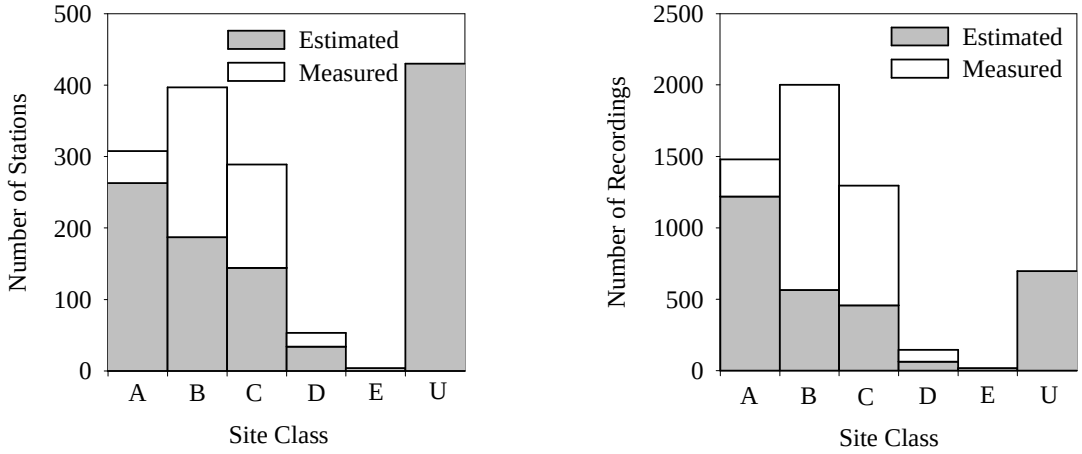

Figure 5. *Distributions of strong-motion stations (left panel) and accelerograms (right panel) in RESORCE in terms of Eurocode 8 (CEN, 2004) site classes. The explanation about the labels designated as "Unknown" is similar to the one given in the caption of Figure 4.*

4. RESORCE review process

The reviewers of RESORCE consist of members of the scientific advisory board for this task (John Douglas, Bruno Hernandez, Lucia Luzi and Gabriele Ameri) as well as the two RESORCE project leaders (Paola Traversa and Fabrice Cotton). In addition, an internal check of the data format and consistency between events, stations and records was conducted by EMSC (Stéphanie Godey and Laurent Frobert). Each version of RESORCE has undertaken a review process before being released.

It has been shown (e.g. Strasser et al., 2009) that variability of ground-motion is well characterized by a lognormal distribution, at least up to three standard deviations. This means that derivations of more than three standard deviations from the median expected ground motion (e.g. PGA) predicted using an appropriate ground motion prediction equation (GMPE) for a given scenario should only be seen about once or twice in every thousand records. This provides a way of quickly checking for large errors in the metadata (e.g. grossly incorrect magnitude), data (e.g. incorrect scale conversion factor) or in assignments of a record to a certain earthquake or station. Such an approach is able to detect large errors in the data or metadata. However, it cannot find errors that do not lead to large residuals. The detection of this type of error was therefore carried out manually.

Other feedbacks of RESORCE were provided by five sets of developers, who produced ground-motion models using RESORCE – 2012. The results of this exercise were published in the February 2014 special issue of Bulletin of Earthquake Engineering.

5. Conclusions

This article summarizes the general features of RESORCE pan-european strong motion database. RESORCE is an up-to-date, homogeneous, integrated European seismic-motion database for developing and testing ground-motion models used in engineering seismology and for earthquake engineering purposes. It only contains validated data and it is released through successive versions.

The various peer reviews of RESORCE undertaken over the past three years have led to a high-quality strong-motion database that will be invaluable for the assessment of seismic hazard in Europe and elsewhere.

The current content of RESORCE includes 5637 multi-component and uniformly processed accelerograms from 1481 events and 1481 strong-motion stations. The moment magnitude range covered by RESORCE is $2.8 \leq Mw \leq 7.8$.

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