RESORCE seismic motion databank : 2011 version, including the improvement of meta-parameters

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A REPORT ON THE RESORCE STRONG-MOTION DATABANK

3rd Progress Report

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1. Introduction

This report gives detailed information about the current progress in RESORCE strong-motion databank (RESORCE SMD) along with studies that have been undertaken in the previous reporting terms.

The previous reports addressed the following items about the RESORCE SMD:

- General features of RESORCE SMD,
- The approach used for selecting the reference accelerometric databases while establishing the RESORCE strong-motion metadata information,
- Differences between the current RESORCE metadata information and the reference accelerometric databases used for establishing the RESORCE SMD,
- Details about the source-to-site distance calculations: flags (assumptions) used in the computation of different distance measures and observed inconsistencies in the computed distances,
- Reasons for removing some of the events and pertaining recordings from the RESORCE SMD.

This report first summarizes the implemented strategy while assembling the RESORCE SMD (by considering the actions taken in the past reports) and then describes the methodology used to surmount the observed inconsistencies in the computed distance measures as well as the additional efforts to complete the missing metadata parameters. The report also addresses the possible influence of uncertainty in metadata parameters on the ground motion estimations computed from the ground-motion prediction equations (GMPEs). The presented discussions in the report will be of use to ensure the quality and reliability of future versions of RESORCE SMD.

2. Strategy followed in compiling the current version of the RESORCE SMD

The information gathered in the current RESORCE SMD is a collection of different accelerometric databases, seismic catalogs and individual studies that are listed in Table 1. In the following paragraphs we first describe the general perspectives of the strategy implemented in the compilation of RESORCE SMD from the beginning of SIGMA project. We then detail the specific rules (hierarchy) that are used for the selection of event- and record-based metadata parameters in the RESORCE SMD. As indicated in the previous RESORCE reports (Şenyurt and Akkar, 2011; Şenyurt et al., 2011) the great portion of the accelerometric databases listed in Table 1 (i.e., the first 6 reference databases in the list) were initially put together under the framework of the project entitled Seismic Hazard Harmonization in Europe (SHARE). The RESORCE SMD is essentially the improved pan-European recordings of the SHARE strong-motion databank (Yenier et al., 2010) in terms of metadata and record processing.

Table 1. Major reference sources in the RESORCE SMD.

Source	# of Records	# of Events	Type of information
Turkish national strong-motion project (T-NSMP, kyh.deprem.gov.tr/fptp.htm)	1795	704	Accelerogram/Metadata
Internet site for European strong-motion data (ISESD, www.isesd.hi.is/ESD_Local/frameset.htm)	1070	607	Accelerogram/Metadata
Italian accelerometric archive (ITACA, itaca.mi.ingv.it/ItacaNet)	761	138	Accelerogram/Metadata
Global Centroid Moment Tensor Catalog Search (G-CMT, globalcmt.org)	749	96	Event-based metadata
European strong-motion database (Ambraseys et al. 2004b)	429	71	Accelerogram/Metadata
Bommer et al. (2007)	159	50	Accelerogram/Metadata
Akkar and Bommer (2010)	21	11	Accelerogram/Metadata
The Next Generation Attenuation Project (NGA, Power et al. 2008)	37	9	Accelerogram/Metadata
Perniola et al. (2004)	56	5	Source information on the 1976 Friuli earthquake (Italy)
Salvi et al. (2000)	45	2	Source information on the 1997 Umbria-Marche earthquake (Italy

Delouis et al. (2002)	38	1	Source information on the 1999 Kocaeli earthquake (Turkey)
U.S. Geological Survey (USGS)	37	2	Event-based metadata
Pace et al. (2002)	27	2	Source information on the 1984 Abruzzo earthquake (Italy)
Berberian et al. (1992)	17	1	Source information on the 1990 Manjil earthquake (Iran)
Hatzfeld et al. (1997)	10	1	Source information on the 1978 Tabas earthquake (Iran)
Walker et al. (2003)	9	1	Source information on the 1995 Dinar earthquake (Turkey)
Anderson et al. (2001)	9	1	Source information on the 1999 Athens earthquake
Tselentis and Zahradnik (2000)	9	1	Source information on the 1995 Kazani earthquake
Haessler et al. (1988)	7	1	Source information on the 1984 Umbria earthquake (Italy)
The Swiss Seismological Service (SED, seismo.ethz.ch)	5	3	Event-based metadata
Kyriazis Pitilakis and Evi Riga (AUTH)			Updated V_{S30} information of some of the Greek sites
Rosenblad et al. (2002)			Updated V_{S30} information of some of the Turkish sites

While assembling the first version of RESORCE SMD (Şenyurt and Akkar, 2011) the accelerometric databases listed in Table 1 (first 8 rows) were studied individually and then incorporated by following a strategy that is explained in this paragraph. This procedure helped us understanding the overall features of these accelerometric databases; particularly for completing a vast majority of missing source-to-site distance information as well as other missing metadata parameters in the latter stages of RESORCE SMD study. In essence this effort resulted in some differences between RESORCE SMD and previously compiled strong-motion databases that contain data from the pan-European region. In the first phase of the study, a total of 2623 common recordings were extracted within from the accelerometric databases that were used to assemble the RESORCE SMD. They were revisited (compared) before they were fully integrated to the 1st version of RESORCE SMD (Şenyurt and Akkar, 2011). The comparison of common recordings were done in terms of country, epicentral coordinate, source-to-site distance measures, depth, magnitude, style-of-faulting, station name and recording type information that were described in detail in Şenyurt and Akkar (2011). These comparisons concluded no major differences in the country, epicentral coordinate, station name and recording type information. However, we found out that magnitude information of common events can differ in the range of 0.3% to 30%. There was also a considerable difference in depth information among the common events. The source-to-site distance differences among the common recordings are significant: in some cases for a given record the distance difference can be one order of magnitude between different databases (Şenyurt and Akkar, 2011). Moreover for some events and for the pertaining recordings we observed that some of the investigated accelerometric databases present either incomplete or inconsistent metadata information. Figures 1-3 illustrate the metadata comparisons of these common events that are already given in Şenyurt and Akkar (2011).

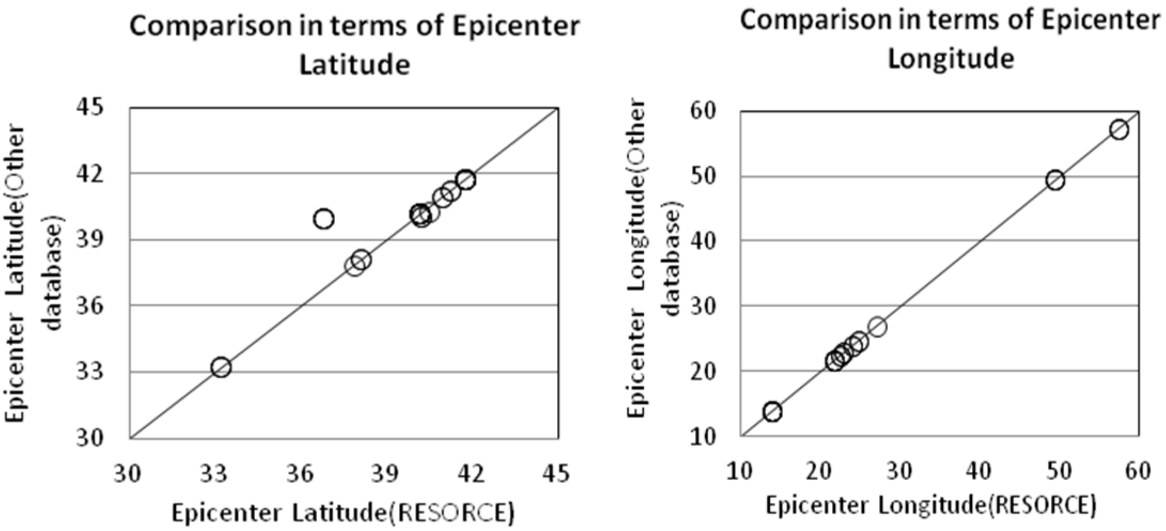

Figure 1.Comparisons of common epicenter coordinate information between the 1st version of RESORCE SMD and the accelerometric databases that are investigated while integrating them into RESORCE SMD.

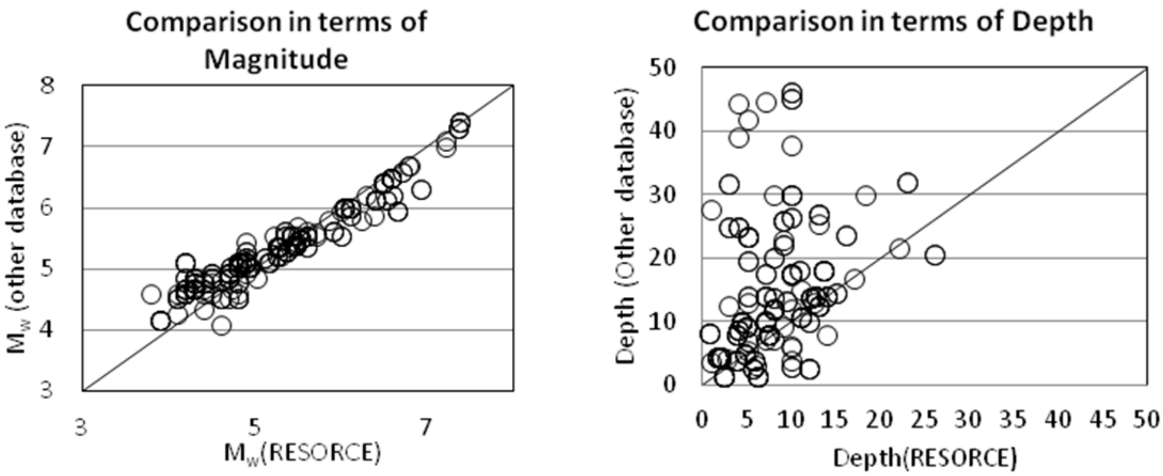

Figure 2 .Similar comparisons as in Figure 1 but for moment magnitude (M_w) and depth (left and right panels, respectively).

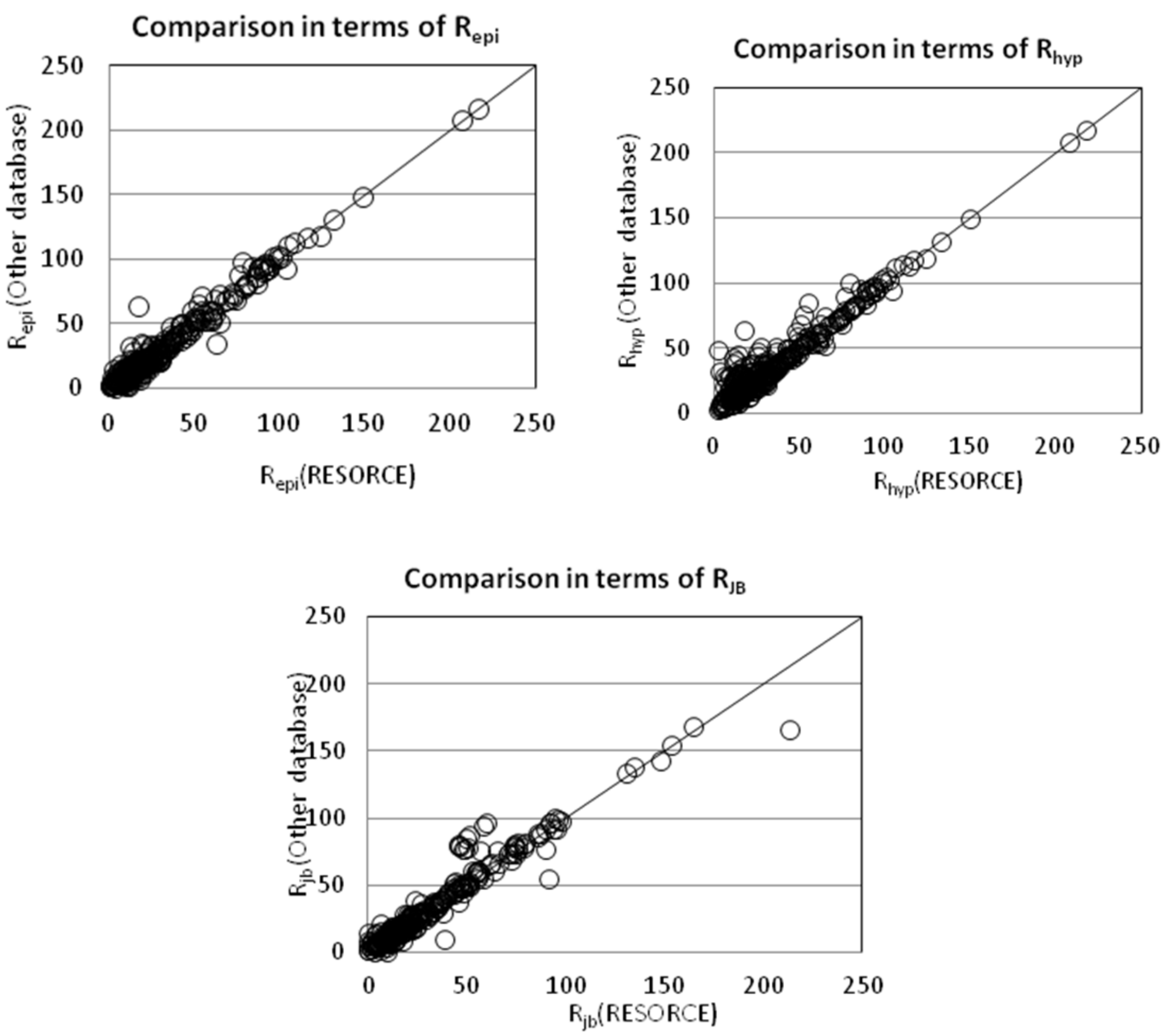

Figure 3. Similar comparisons as in Figure 1 but for R_{epi} (1st row, left panel) R_{hyp} (1st row, right panel) and R_{jb} (2nd row).

After identifying the above deficiencies the rest of the reference sources listed in Table 1 (rows between 9 and 22) were used to improve the metadata information of the RESORCE SMD. The reference sources (given between rows 9 and 22 in Table 1) were also used to re-compute R_{epi}, R_{hyp}, R_{jb}, and R_{rup} (i.e., epicentral, hypocentral, Joyner-Boore and rupture distance metrics, respectively) that were identified as either missing or inconsistent during the comparative studies as described in the above paragraphs as well as additional observations on the relationships between computed different distance measures. The source characteristics of some individual events (based on the literature survey conducted by John Douglas) and tracing of some well-known earthquake catalogs (e.g., G-CMT and SED) updated the event-based information for many earthquakes in the RESORCE SMD and led the calculation of incomplete or inconsistent distance measures. The distance calculations were made through some assumptions that are explained in the *Source-to-Site Distance Measures* section. Figures 4-6 show the comparisons given in Figures 1-3 by considering the recent modifications in RESORCE SMD that are described in the above lines. As an additional remark we should note that the above studies have improved the country specific strong-motion databases (i.e., ITACA and T-NSMP) significantly.

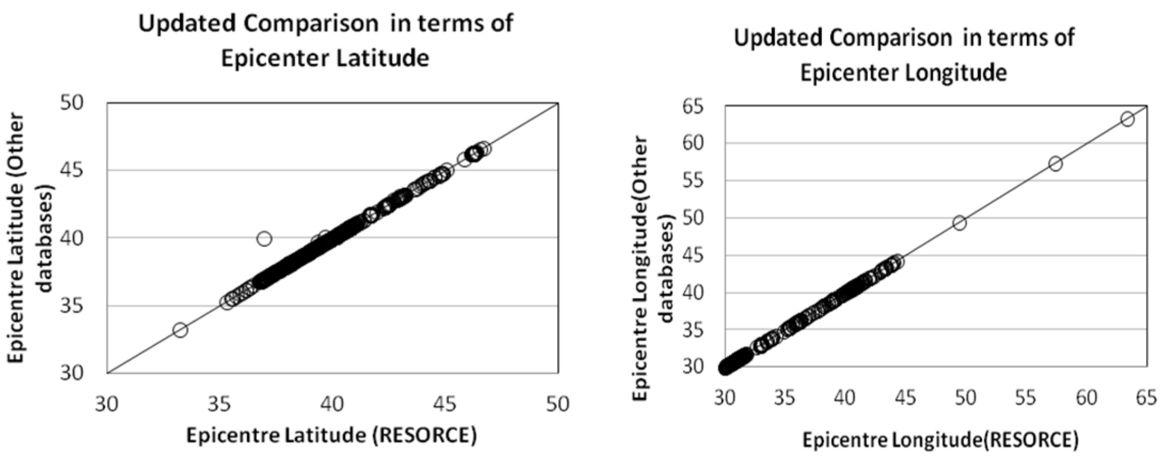

Figure 4. Comparisons of common epicenter coordinate information between the current version of RESORCE SMD and the accelerometric databases that are investigated while integrating them into RESORCE SMD.

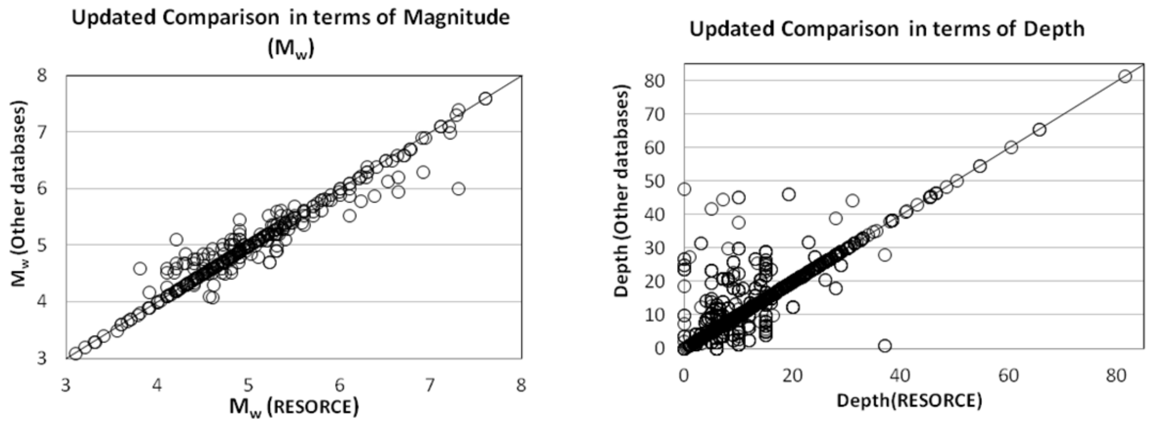

Figure 5. Similar comparisons as in Figure 4 but for moment magnitude (M_w) and depth (left and right panels, respectively).

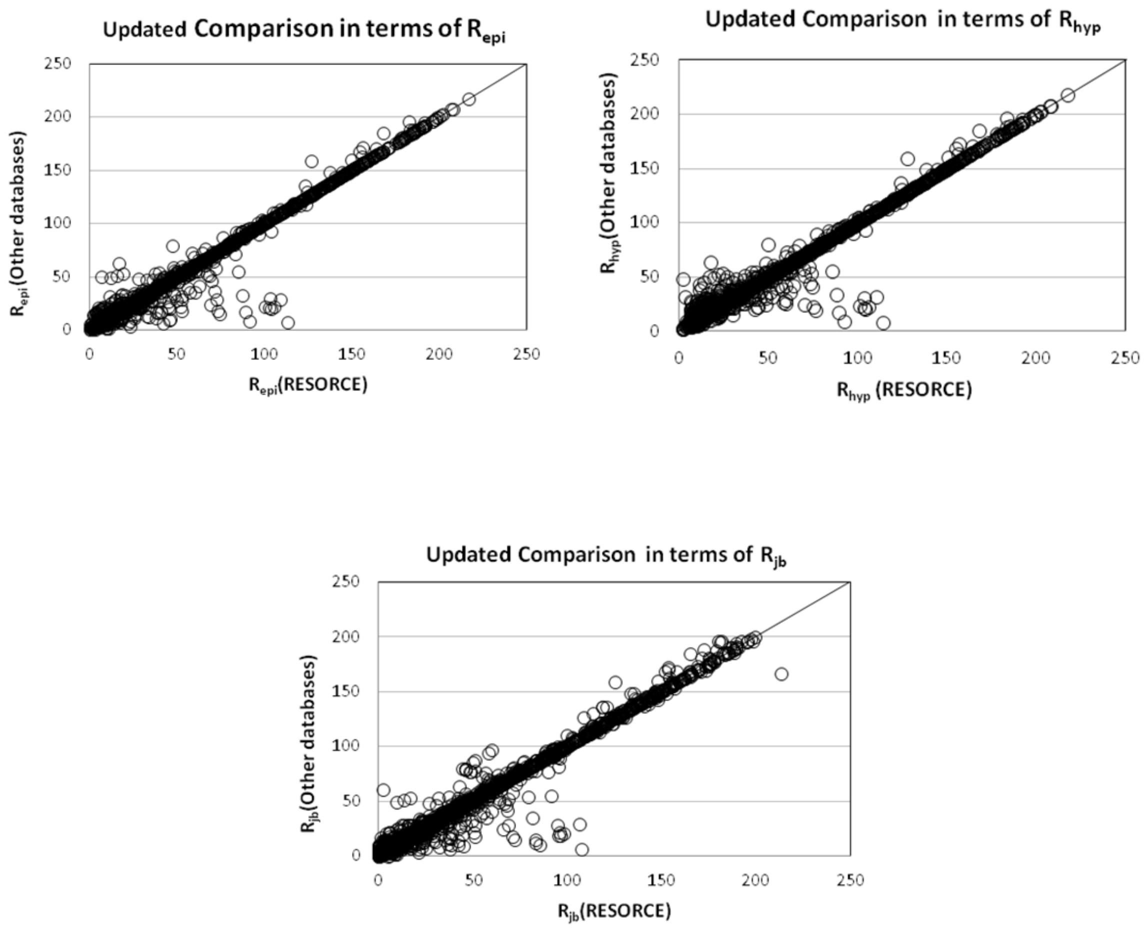

Figure 6. Similar comparisons as in Figure 4 but for R_{epi} (1st row, left panel) R_{hyp} (1st row, right panel) and R_{jb} (2nd row).

While improving the RESORCE SMD the overall hierarchy implemented is described in the following bullets:

- Use local databases as the primary reference source since most of them contain the updated metadata and waveform information through national strong-motion projects [e.g., recently recompiled Turkish (Akkar et al., 2010) and Italian (Luzi et al., 2008) databases],
- If no information (or insufficient information) exists in the local databases, refer to below databases with the following order:
    - ESMD
    - ISESD
    - NGA

  The preferred order listed above is waived whenever one of the databases contains the most complete information on the metadata parameters of interest,
- Use the information given in ESMD, ISESD or NGA for recordings (or events) other than Italy and Turkey. The priority among these databases is given above. However, for a given event (or recording), if one of the above databases has more complete metadata information (in particular more complete information on source parameters as they are significant for source-to-site distance calculations), prefer that database,
- Use available literature for definite (the most reliable) metadata information for some of the well-known events that are listed in Table 1,
- For events whose metadata information cannot be fully completed refer to international earthquake catalogs that are listed in Table 1.

The last 2 steps in the above strategy were incorporated and applied in Şenyurt et al. (2011). This way we tried prevailing the observed inconsistencies in the previously reported source-to-site distance measures as well as to obtain more reliable event-based metadata information for the RESORCE SMD.

3. Information on RESORCE SMD Metadata

The current version of RESORCE SMD consists of 5290 strong-motion recordings from 1680 earthquakes and their metadata parameters. In the first version of the databank (Şenyurt and Akkar, 2011) the total number of recordings was 5281 and the total number of events was 1734. In the second version these numbers were 5115 and 1685, respectively (Şenyurt et al., 2011). The size of the databank was decreased in the second version because the events and pertaining recordings that fail to contain the most important metadata parameters (e.g., station coordinates that are indispensible to compute source-to-site distances) were removed. In the current version, small magnitude aftershock recordings of the 2007 Bala Earthquake are removed. These aftershock events do not contain reported M_w value from any of the searched seismic agencies. On the other hand, we have included a total of 129 recordings from 5 recent events that occurred in Turkey in 2010 (M_w 6.1 Elazığ–Kovancilar, earthquake and its major aftershock) and 2011 (M_w 6 Kütahya-Simav, M_w 7.1 Van and M_w 5.6 Edremit, earthquakes). In addition to these updates, a total of 180 recordings that are additionally extracted from Akkar and Bommer (2010) and Bommer et al. (2007) studies are included in the RESORCE SMD. The additional recordings are mainly from small-magnitude events of Switzerland, Italy and Spain. Although they are complete in terms of event information, they lack station information that should be improved in the future report terms via collaboration with SIGMA project management.

The metadata of the current version of the databank includes the following information:

<u>Earthquake information</u>: Earthquake Id, event information from reference source[1], earthquake code, earthquake date, earthquake time, earthquake name (if available), earthquake country, country code, epicentre coordinates, focal depth (if available), magnitude in various scales (i.e., M_w, m_b, M_S, M_d and M_L; whenever all or some are available), style-of-faulting (if available), earthquake source geometry (rupture length, rupture width, depth-to-top of rupture, plunges and azimuth angles of P- and T-axis, strike, dip, slip information for the available fault-plane solutions, whenever available).

[1] Reference source for event information refers to the database or specific paper from the literature where the event information is gathered for the RESOURCE SMD.

Station information: Station Id, station information from reference source[2], station id from reference source, station name (if available), station network (if available) and station operator (if available), station country, station country code, station coordinates, altitude (if available), station shelter type (if available), V_{S30} information (if available), V_{S30} measurement information (measured or inferred, if measured type of measurement), site class estimation according to Eurocode 8 (CEN, 2004) classification and site class information from reference source (i.e., agency that reports the site class from geology).

Accelerogram (Waveform) information: Waveform Id, distance flag, source-to-site distances (i.e., R_{epi}, R_{hyp}, R_{jb}, R_{rup}; if available), instrument model (if available), recording type (analogue vs. digital; if available), component orientation (if available), data processing information (whenever available type of processing, type of digital filter, low- and high-cut filter values used in the processing of each component and suggested usable long-period spectral ordinate for horizontal component), peak ground motion amplitudes of each component.

[2] Reference source for station information refers to the database or specific paper from the literature where the event information is gathered for the RESOURCE SMD.

4. Seismological features of the current version of the RESORCE SMD

As indicated in the previous section, we disregarded some of the data as they do not contain the fundamental metadata information for their efficient use in seismological studies. We also added more data from different events thus the seismological features of the current database are changed with respect to the previous 2 reports. The updated yearly distribution of strong-motion recordings and events in the current RESORCE SMD are given in Figure 4.

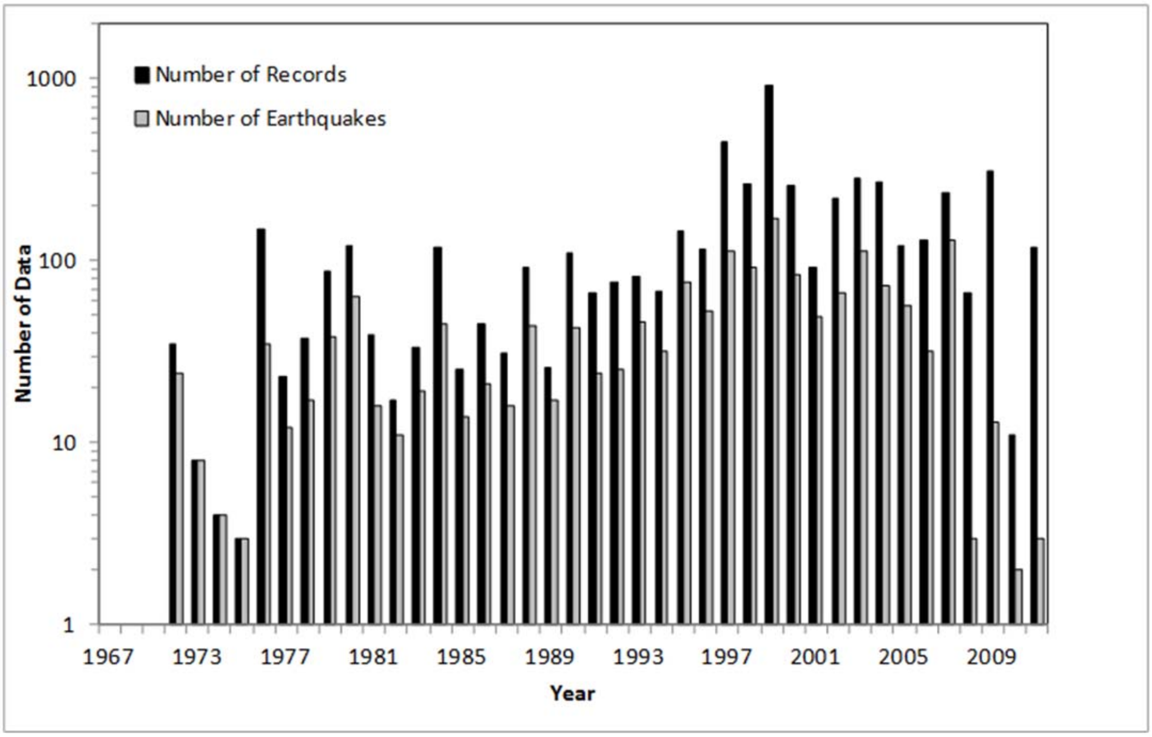

Figure 7. Yearly distribution of recordings and events in the current version of the RESORCE SMD

Table 2 presents the geographic (country-based) distribution of strong-motion accelerograms and events in the RESORCE SMD. Most of the strong-motion recordings are from Turkey and Italy. Almost all of these recordings are from the shallow active crustal regions in Europe and surrounding countries. The sub-sections that follow Table 2 describe the current states of the major metadata parameters in RESORCE SMD.

Table 2. Countries contributing to the RESORCE SMD

EQ Country	# Record	# Event	EQ Country	# Record	# Event
Turkey	2028	725	Norway	10	7
Italy	1425	303	Syria	10	1
Greece	515	286	Egypt	9	3
Iran	396	44	Macedonia	9	3
Iceland	212	48	Serbia	8	8
Portugal	125	60	Austria	7	3
Switzerland	89	27	Israel	6	3
Montenegro	59	22	Albania	5	4
Spain	54	21	Kyrgystan	5	2
Georgia	43	11	Cyprus	4	3
Armenia	40	14	Liechtenstein	4	1
Germany	35	13	Bulgaria	3	1
France	34	15	Netherlands	3	1
Romania	32	4	United Kingdom	3	3
Slovenia	32	14	Caucasus	1	1
Uzbekistan	30	13	Hungary	1	1
Algeria	28	22	Lebanon	1	1
Bosnia and Herzegovina	13	7	Saudi Arabia	1	1
Croatia	10	9			

4.1. *Magnitude distribution*

Figure 8 presents the distribution of events (Figure 8.a) and strong-motion recordings (Figure 8.b) in terms of M_w. 741 events out of 1680 have direct M_w information in the databank. 439 earthquakes lack direct M_w information but they are estimated by an empirical magnitude relationship. These are designated as *estimated* M_w in the given histogram. These earthquakes are from the Turkish strong-motion database and estimations are made by the empirical equations proposed by Akkar et al. (2010). When the number of recordings is of concern, 3524 recordings out of 5280 have direct Mw information whereas a total of 867 recordings (accelerograms from the Turkish database) have "*estimated*" M_w values (as explained in the previous sentence). If this approach is accepted as a reliable methodology, it can be applied to the Italian events in the databank that are currently designated as unknown in Figure 8. The empirical magnitude relationship (Castellaro et al; 2006) derived specifically for the Italian strong-motion events can be used for this specific purpose. Such an additional effort would result in the estimation of M_w values for 127 Italian events (260 Italian recordings).

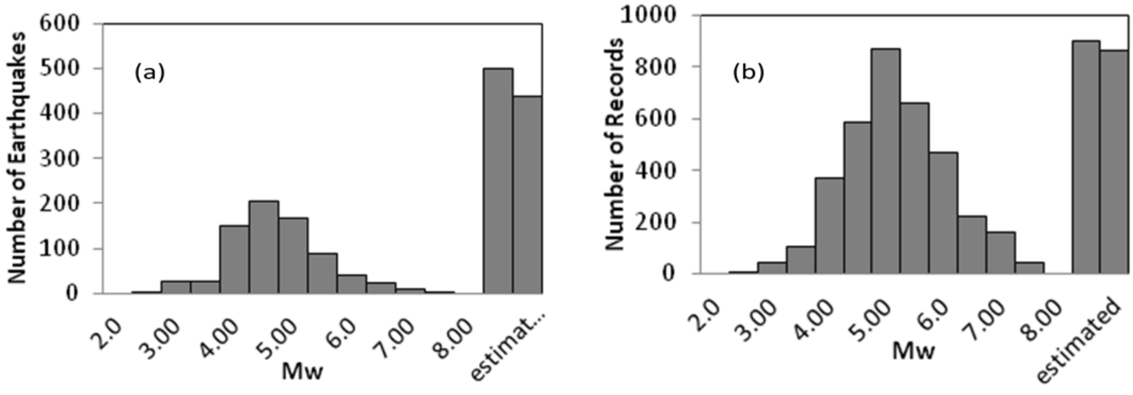

Figure 8. (a) Event and (b) recording distribution in terms of M_w

4.2. *Depth distribution*

The focal depth distribution of events and strong-motion recordings are plotted in Figure 9. Among the entire database approximately 90% of data have focal depths less than 20 km. As a future study the depth information of the RESORCE SMD can be improved for some events whose depths were computed from the sparse seismic data.

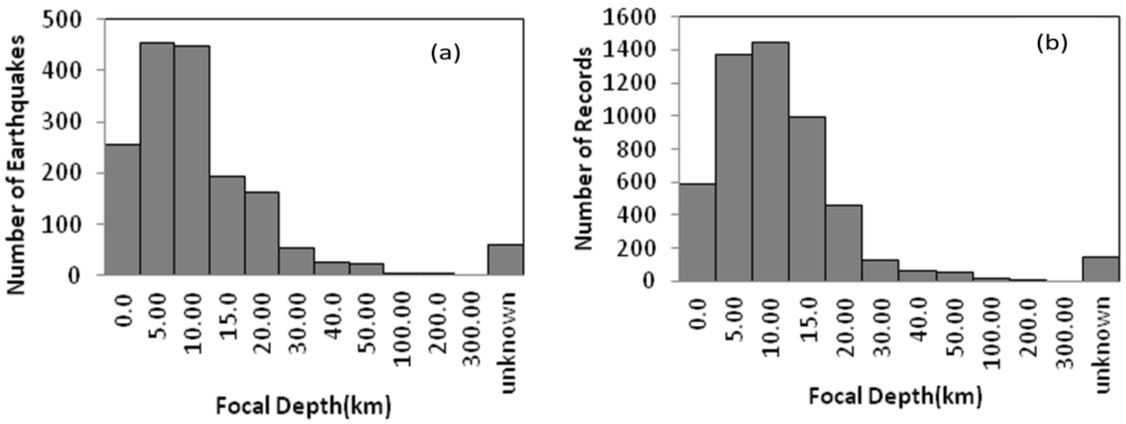

Figure 9. (a) Event and (b) recording distribution in terms of focal depth

4.3. *Style-of-Faulting Distribution*

The style-of-faulting (SoF) information provided by the reference databases is not uniform in the first version of the RESORCE SMD. We used plunge and rake angles of the events in the databank and implemented the SoF classification proposed in Boore and Atkinson (2007) in order to obtain a uniform SoF information in the current version of the RESORCE SMD. The following items summarize the implemented criteria for this process:

- If plunge angles are available, determine the SoF by considering the rules listed in Table 3,
- If plunge angles are not directly available but strike, dip and rake angles are known, use the computer code of Snoke (Snoke, 2003) to compute the plunge angle and determine the SoF by considering the rules listed in Table 3,
- If plunge angle yields undefined SoF and if rake angle is known, use the rules listed in Table 4.

Table 3. Criteria of style-of-faulting classification using plunge angles

Style of Faulting	P-axis plunge (P-pl) angle	T-axis plunge (T-pl) angle
Normal	P-pl>40	T-pl<40
Reverse	P-pl<40	T-pl>40
Strike-slip	P-pl<40	T-pl<40
Undefined	P-pl>40	T-pl>40

For events whose fault-plane solutions could not be determined from any one of the reference sources listed in Table 1 but their faulting mechanisms are directly described by the relevant reference database, we accepted that information as is. Table 5 shows our strategy in determining the SoF information of such cases.

Table 4. Criteria of style-of-faulting classification using rake angles

Style of Faulting	Rake angle (λ)
Normal	$-150 \leq \lambda \leq -30$
Reverse	$30 \leq \lambda \leq 150$
Strike-slip	$-180 \leq \lambda < -150$, $-30 < \lambda < 30$ and $150 < \lambda < 180$

Table 5. Criteria used when only faulting mechanism is provided by the reference databases

Style of Faulting-Provided	Style of Faulting-Used
Normal	Normal
Normal-Oblique	
Reverse	Reverse
Reverse-Oblique	
Strike-slip	Strike-slip
Oblique	Oblique

Figure 10 shows the distribution of events (Figure 10.a) and strong-motion recordings (Figure 10.b) as a function of SoF. A significant number of events (especially small magnitude earthquakes) lack the SoF information in the databank. However, this size of unknown SoF information is relatively small in terms of number of recordings (Figure 10.b). As it can be inferred from these histogram plots the majority of events and strong-motion recordings are either strike-slip or normal those are followed by reverse faulting mechanism.

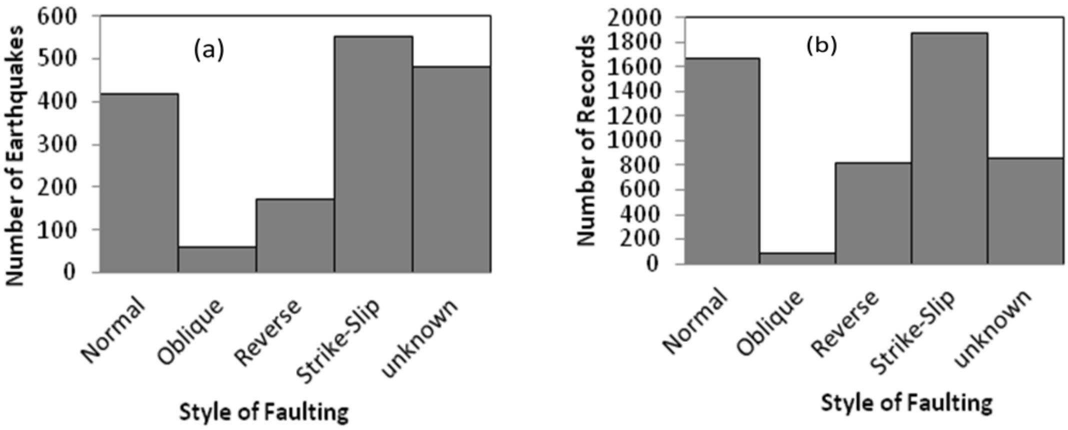

Figure 10. (a) Event and (b) recording distribution as a function of style-of-faulting

4.4. *Site Class Distribution*

With the recent improvements in site information the current version of the RESORCE SMD contains a total of 465 strong-motion stations with known V_{S30} values. The corresponding number of accelerograms recorded at these stations is 2907. The metadata of the databank also contains information about the type of applied in-situ measurement for the calculation of shear-wave velocity profile (Table 6). The number of recording sites with site classes inferred from the local geological conditions is 466 and the corresponding number of accelerograms is 1397. A total of 986 recordings (18% of the total number of recordings in the databank) do not have any information about soil classification. Table 7 shows strong-motion sites that recorded more than 10 strong-motion recordings without any site class information. Figure 11 shows the distribution of accelerograms as a function of EC8 (CEN, 2003) site classification. The light-gray vertical bars in the histogram plot show the site-classification statistics in terms of V_{S30} (measured). The darker vertical bars show the site classification of strong-motion recordings that are inferred from the local site geology. The last vertical bar in this figure shows the accelerograms that lack site classes. Figure 11 indicates that most of the data in the

RESORCE databank pertain to EC8-B and EC8-C soil categories (i.e., 180m/s ≤ V_{S30} < 360 m/s and 360 m/s ≤ V_{S30} < 800 m/s). The percentage of recordings falling into the other EC8 site classes are given in the following bullets.

- ~18% of the data are recorded at rock sites (EC8-A; V_{S30} ≥ 800 m/s)
- ~2% of the data are recorded at very soft sites (EC8-D; V_{S30} < 180 m/s)

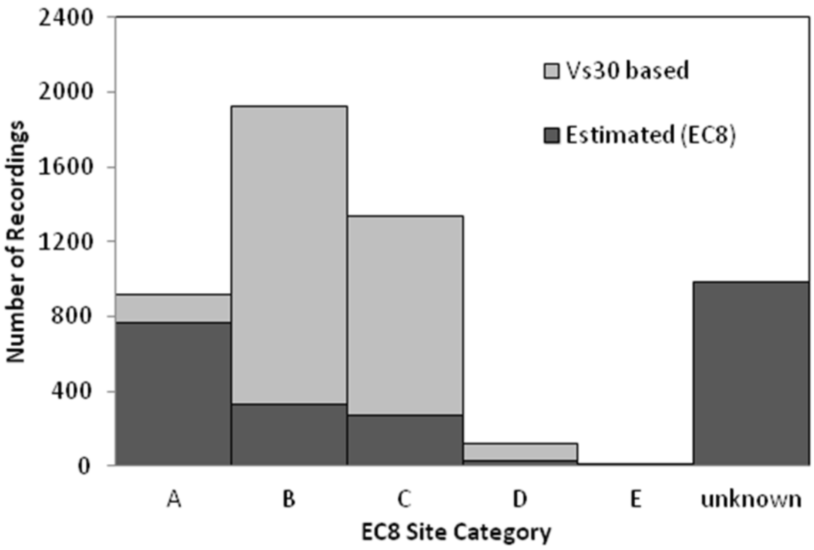

Figure 11. Strong-motion recording distribution as a function of EC8 site classification

Table 6. In-situ site measurements of the RESORCE strong-motion recording stations

Abbreviation	Measurement description
CH	Seismic cross-hole
DH	Seismic down-hole
ESAC	Extended spatial autocorrelation mehtod from microtremor arary measurements
ESAC-FK	Frequency wavenumber spectrum method from microtremor array measurements
MASW	Multi-channel analysis of the surface waves
SASW	Spectral analysis of surface waves

Table 7. Strong-motion sites that recorded more than 10 recordings without any site class information

STATION ID	STATION NAME	STATION COUNTRY	# Record
2890	Genio-Civile	Italy	21
2933	Beni Rashid	Algeria	13
2932	El Safsaf	Algeria	12
2995	Serennes-Ecole	France	12
3385	Sao Sebastiao Escola (Terceira)	Portugal	10

4.5. ***Source to Site Distance Measures***

The computation of R_{epi} and R_{hyp} distance measures are straightforward and will not be described in detail. The following set of rules is applied while re-computing the R_{jb} and R_{rup} distance measures. The rules presented in the below strategy are identified by flags in the RESORCE SMD. The flag numbers are defined next to each option.

i. When true fault-plane is known (Flag #1):

   Nucleation point is assumed to be at the center of the fault (if this information is not provided by the relevant literature for a specific event).

   Fault dimensions (width and length) are computed from the empirical equations proposed by Wells and Coppersmith (1994) (if this information is not provided by the relevant literature for a specific event).

   The finite fault distance mesaures (R_{jb} and R_{rup}) are calculated by the procedure proposed by Kaklamanos et al. (2011).

ii. When double-couple fault plane solutions are provided without identifying the true fault plane (Flag #2):

   Follow the above steps (assumptions) for the computation of extended-source distance measures for both planes.

   Assign the arithmetic average of the distances computed from both planes as the corresponding source-to-site distance measure.

iii. When double-couple fault plane solutions are not provided:

   a. If $4.0 \leq M_w \leq 5.5$, depth $\leq$ 30 km and SoF different than oblique use an iterative procedure that uses R_{epi} information to compute R_{jb} from the Scherbaum et al. (2004) methodology (Flag #3). A similar approach can also be used to calculate (or estimate) R_{rup} from R_{jb}, which is partially done in the current version of the RESORCE databank.

b. If $M_w < 4.0$ or $M_w > 5.5$ or depth > 30 km or SoF is undefined, do not make any attempt to compute (or estimate) R_{jb} or R_{rup} (Flag #4).

c. Unreported station coordinates of the recordings that are additionally extracted from Akkar and Bommer (2010) and Bommer et al. (2007) studies (Flag # 5)

Figure 12 shows the scatter plots of recordings in terms of different distance measures that are computed by following the above strategy. In the current version of RESORCE SMD all recordings (5290) have R_{epi} values. Number of recordings that contain R_{hyp} information is 5125. A total of 4084 accelerograms have R_{jb} values whereas this number is 2790 in terms of R_{rup} information.

Figure 13 gives the relationships between different distance measures that is also presented in the first draft report. As it can be inferred from these updated plots the inconsistencies spotted in the previous version of the RESORCE SMD do not exist anymore. This is due to the extensive survey conducted on the earthquake catalogs as well as the literature study on some of the specific events that are realized after delivering the first progress report.

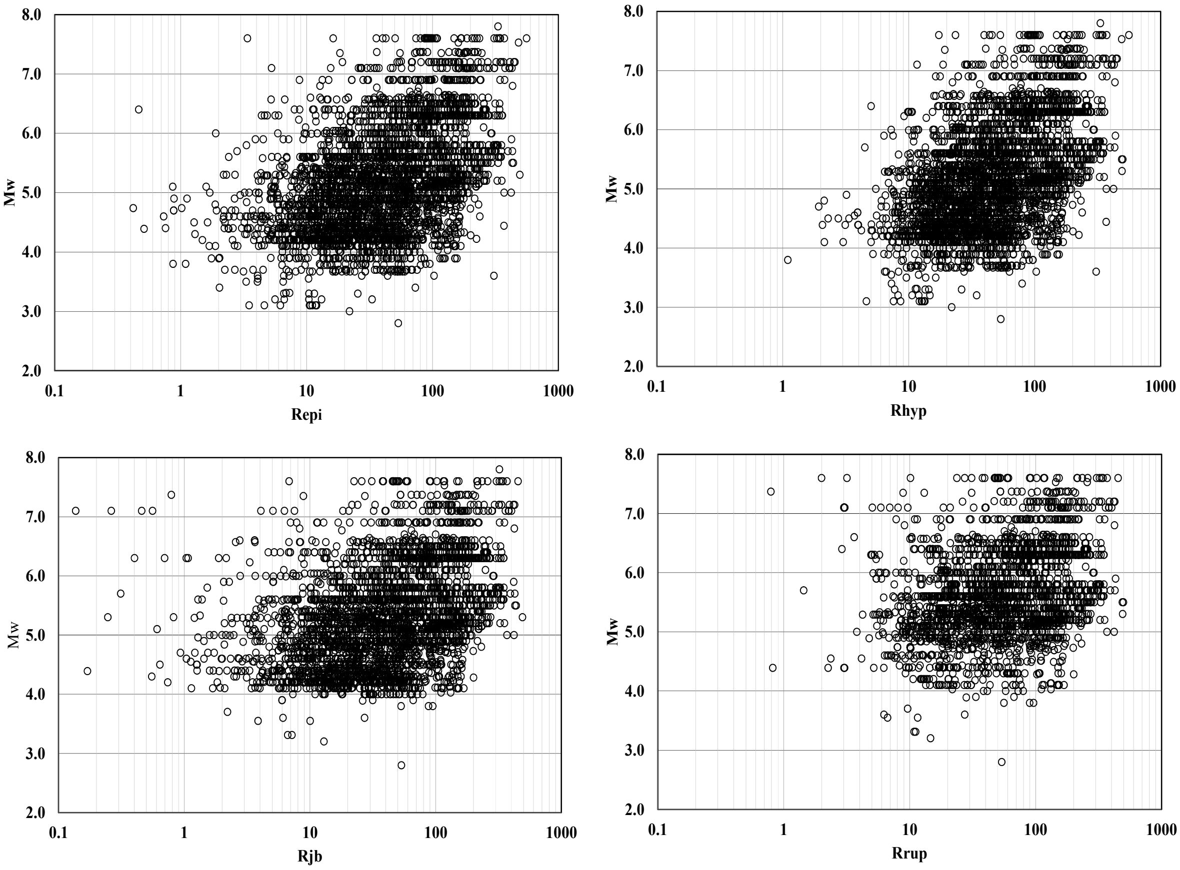

Figure 12. Distribution of recordings for different source-to-site distances as a function M_w

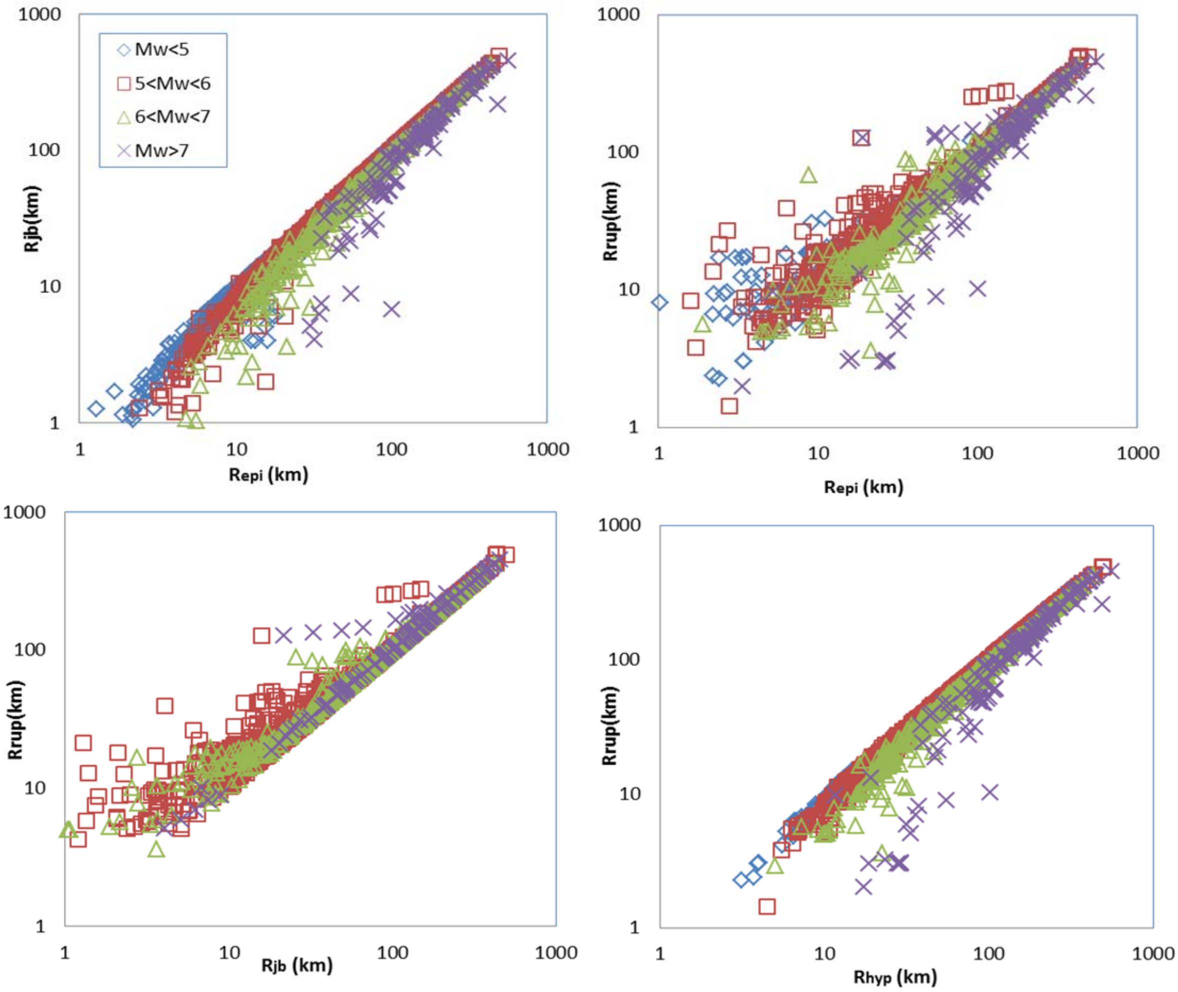

Figure 13. Relationships between different source-to-site distance measures in the current RESORCE strong-motion databank.

5. Uncertainty Studies on Major Metadata Parameters

The influence of metadata uncertainty is investigated by considering the Turkish strong-motion database (abbreviated as T-NSMP in RESORCE SMD) as this database contains metadata information from different seismological sources (Table 8). The final metadata parameters of T-NSMP are established using a hierarchical order among these reference sources as described in Akkar et al. (2010). This section first describes the associated uncertainty in magnitude, depth and distance due to different information reported by individual reference sources. The subsequent section follows this discussion by showing case studies to see the extent of this uncertainty to ground-motion predictive models that are the most prominent components in hazard assessment.

Table 8. Preferred order of seismological sources (full names of the acronyms are given in Appendix) while establishing the metadata parameters in T-NSMP (modified from Akkar et al., 2010).

Preference Order	Event Time	Epicenteral Coordinates	Depth	M_w	Fault-Plane Solution
1	GDDA	ISC	ISC	HRV	HRV
2	USGS	GDDA	GDDA	SED	SED
3	ANSS	ISK	ISK	ANSS	RCMT
4	ISC	ANSS	ANSS	RCMT	ESMD
5	ISK	USGS	USGS	USGS	USGS
6	HRV	SED	HRV	ESMD	Bohnhoff et al. (2006)
7	SED	RCMT	SED	EMMA	Kiratzi and Louvari (2003)
8	RCMT	ESMD	RCMT	CSEM	Ozalaybey et al (2002)
9	EMMA	EMMA	EMMA	ISK	Ergin et al (2004)

5.1. Moment Magnitude Uncertainty

A total of 996 events out of 2994 have moment magnitude (M_w) information in T-NSMP. The M_w values of these events range from 1.60 to 7.23. In order to examine the M_w differences between various data sources (seismic agencies and literature as listed in Table 8), events with M_w information from a unique source are excluded. The differences in M_w for the remaining 163 events that range between $3.78 \leq M_w \leq 7.23$ are investigated in the context of this study. Figure 14 shows the number of events with M_w information provided by different sources. The M_w values of most of the events are provided by 4 or less number of seismological sources. The interpretation of this observation would suggest that the uncertainty in M_w information originates mostly from a limited number of seismological sources.

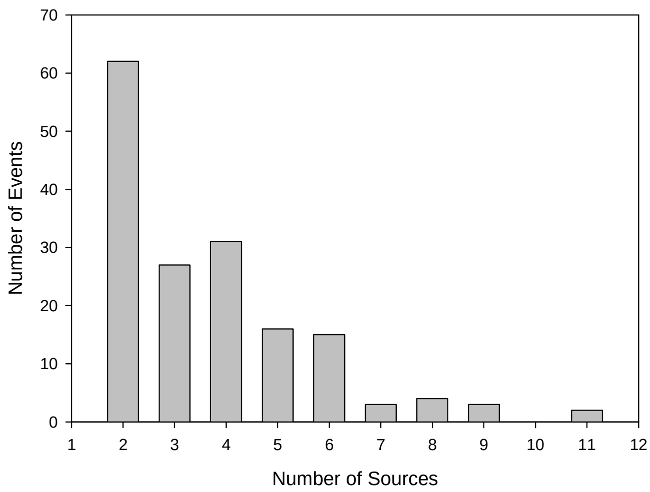

Figure 14. Number of seismological sources providing M_w information.

Figure 15 depicts the relationship between M_w and the corresponding average number of available seismological sources. It shows that the event size and the number of available seismological sources that provide M_w are proportional to each other. In other words, for large magnitude events, the average number of sources that provides M_w increases.

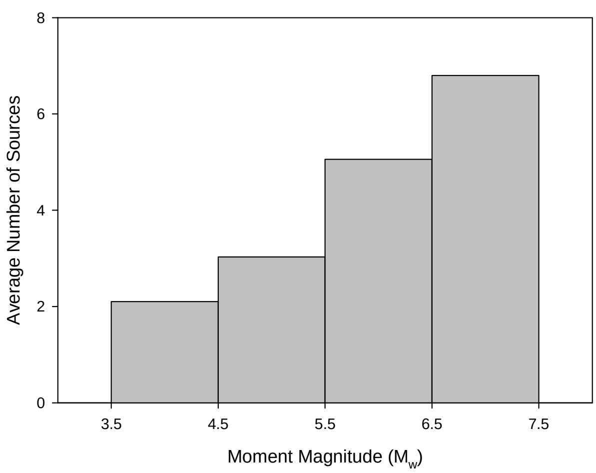

Figure 15. Average number of available seismological sources with respect to event size given as M_w

Figure 16 quantifies the M_w uncertainty in 163 events by showing the differences between the preferred and reported moment magnitudes from different seismological sources. As indicated in the above paragraphs the preferred M_w is established by utilizing a hierarchical order described in Akkar et al. (2010). The events follow a chronological order: proceeding from older events to the most recent ones in the database. The scatters in Figure 16 loosely suggest a decrease in the level of magnitude uncertainty towards more recent events. Figures 17 and

18 show similar sketches for magnitude uncertainty in terms of event size. Figure 17 is a scatter plot similar to Figure 16 in which the data are sorted against increasing event size. Figure 18 shows the same type of information as in Figure 17 but the ordinates on this graph describes the variation of average absolute magnitude difference between the preferred and reported M_w from different seismological sources. The average absolute magnitude difference is the absolute magnitude differences between the preferred and other seismological sources normalized by the total number of observations for the magnitude intervals given in Figure 18 that are divided by vertical lines. Both Figures 17 and 18 indicate that the event size has a dominant effect on magnitude uncertainty that is more apparent in Figure 18.

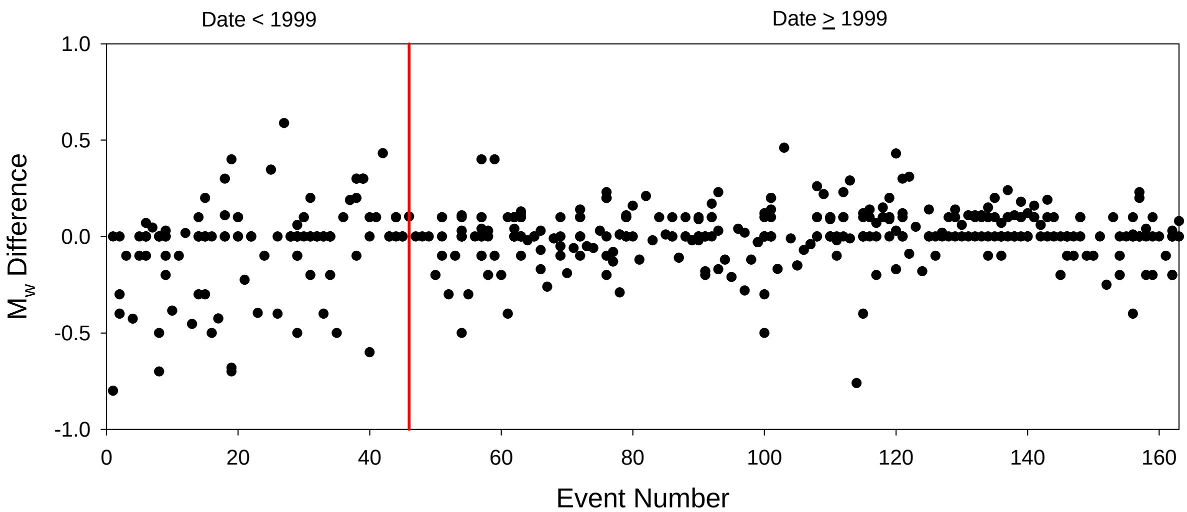

Figure 16. M_w difference between the preferred and different seismological sources as a function of event date.

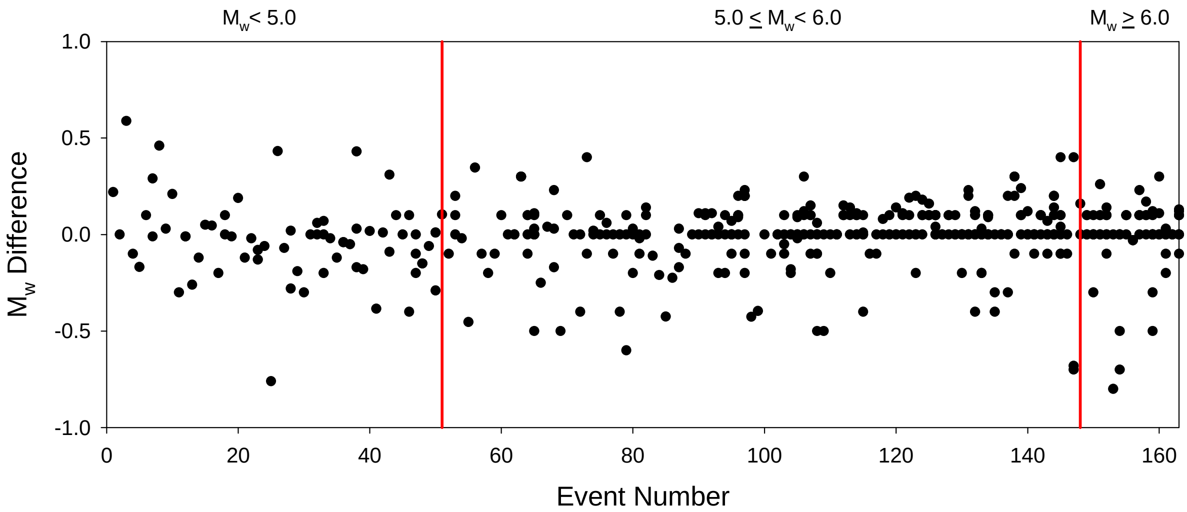

Figure 17. Same as in Figure 16 but the data are sorted with increasing magnitude.

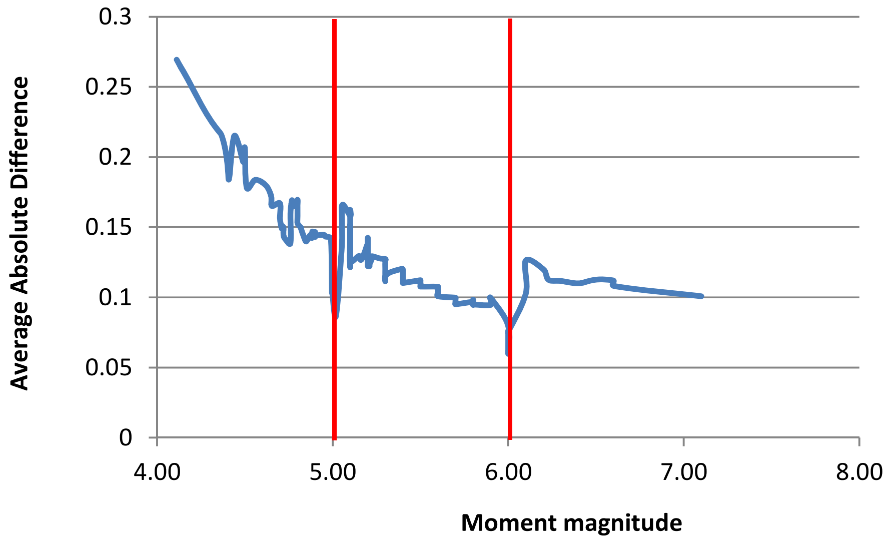

Figure 18. Variation of average absolute magnitude difference as a function of magnitude.

5.2. Depth Uncertainty

The T-NSMP consists of 1848 events having depth information gathered form 2 or more seismological sources. Similar to the magnitude case, the depth uncertainty is quantified as the difference between the preferred and other depth values provided by different seismological sources. The scatter plot in Figure 19 shows the depth uncertainty for the 1848 events that are sorted in chronological order. On average the depth difference is ± 15km for the considered events; an interval that is not negligible since almost entire T-NSMP consists of crustal events. The scatters in Figure 19 do not show a correlation between the date of occurrence of events and the depth uncertainty.

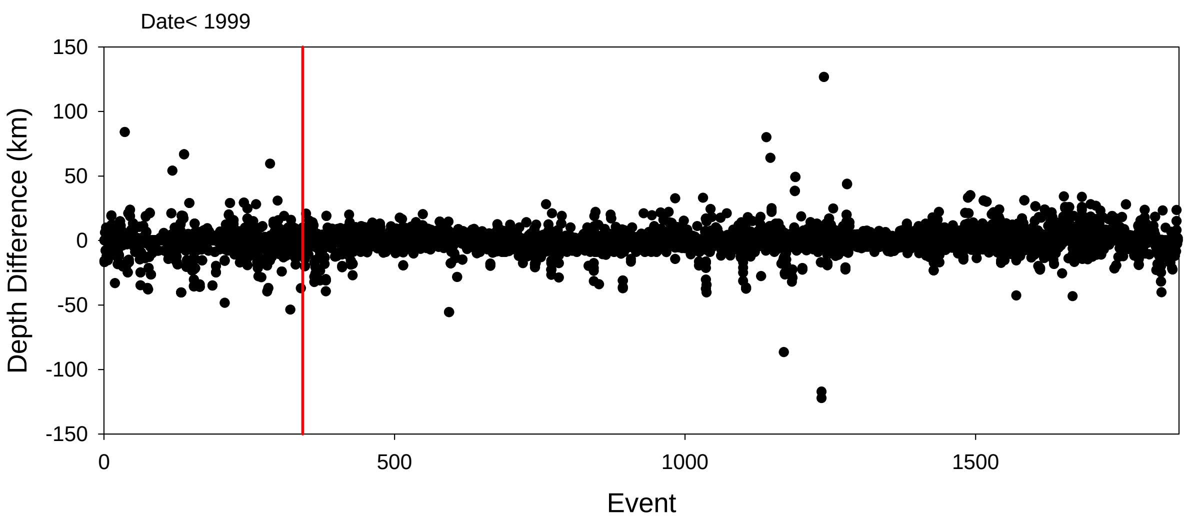

Figure 19. Depth difference between the preferred and different seismological sources as a function of event date.

The influence of event size on depth uncertainty is also investigated by extracting a subset from the above dataset using the events with known magnitudes. The depth uncertainty scatters of this subset, which consists of 932 events, are given in Figure 20 as a function of magnitude. This plot does not show any clear dependency of magnitude uncertainty on the event size. The common observation from these figures is that the depth uncertainty should not be overlooked in a database and it is significant regardless of the event time and the size of the event.

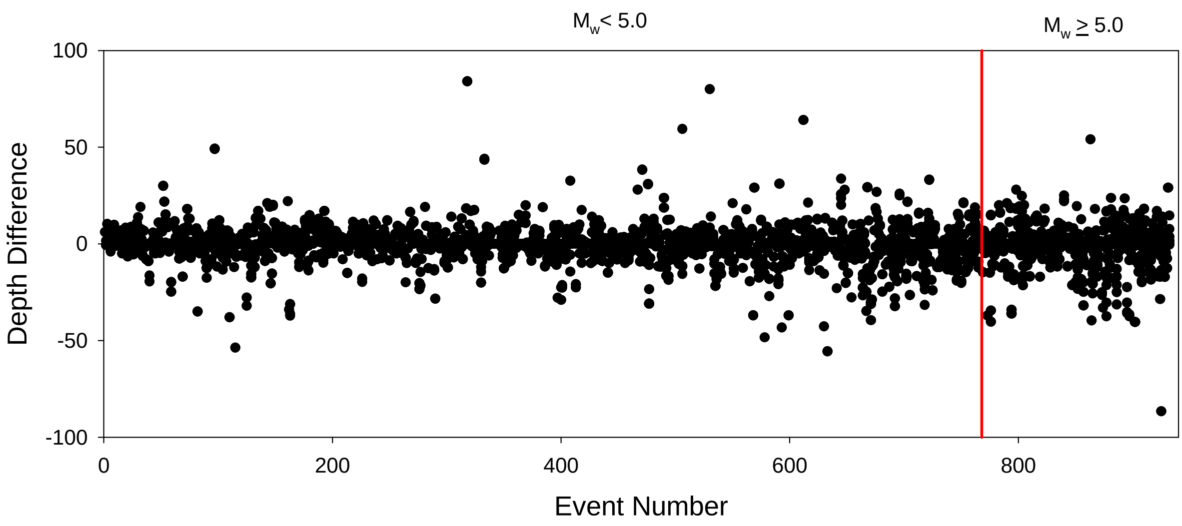

Figure 20. Depth difference between the preferred and different seismological sources in terms of increasing event size.

5.3. Source-to-Site Distance Uncertainty

A total of 7 different seismological sources can provide the required event information (i.e., epicentral coordinates, moment magnitude, depth and fault-plane solution) for the calculation of source-to-site distance measures (R_{epi}, R_{rup}, R_{jb} and R_{hyp}). The variability in these metadata parameters affects the uncertainty in the computation of distance metrics. Table 9 shows the contribution of each of these metadata parameters to the considered distance measures in this chapter. The number of records and events in T-NSMP are 768 and 248, respectively for running the comparative analysis to understand the source-to-site distance uncertainty as in the cases of magnitude and depth. The uncertainty in distance measures is quantified either by the distance differences or normalized distances computed from the preferred and other seismological sources. Source-to-site distances computed from preferred metadata information are used as divisors in the normalized distance calculations. The computation of extended-source distance measures are done by following the Kaklamanos et al. (2011) procedure as described in the previous chapter.

Table 9. Contribution of event parameters to distance calculations

R_{epi}	R_{hyp}	R_{JB}	R_{rup}
Epicentral coordinate	Epicentral Coordinate	Epicentral Coordinate	Epicentral Coordinate
	Depth	Magnitude	Magnitude
		Fault-plane solution	Depth
			Fault-plane solution

Figure 21 shows the variation of distance uncertainty in terms of normalized epicentral distances ($R_{epi(source)}/R_{epi(preferred)}$). The abscissa in this plot is given as the epicentral distances computed from the preferred metadata parameters. The scatter in the given figure is significant for recordings closer to the epicentral area (i.e., R_{epi} < 30 km). The epicentral distance differences between the preferred and other seismological sources can be in the order of magnitude or sometimes more. The observed difference decays rapidly as the recordings move further away from the epicentral area. Although not given in this report similar type of comparisons for R_{hyp}, R_{jb} and R_{rup} also reveal similar trends. These observations suggest that the distance uncertainty is significant for close-distance recordings regardless of the distance measure.

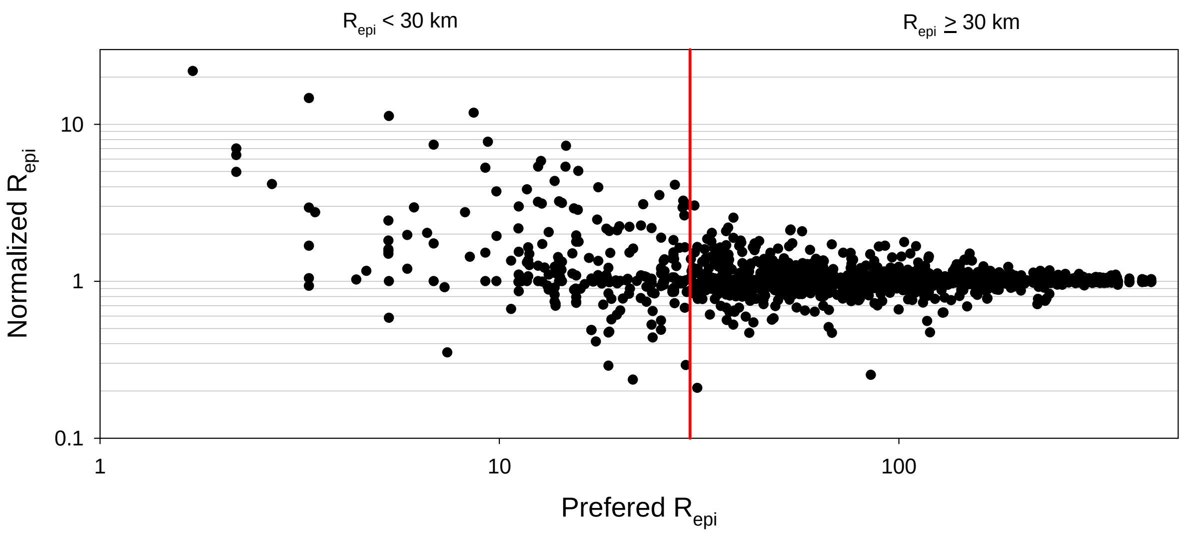

Figure 21. Uncertainty in R_{epi} in terms of normalized R_{epi} ($R_{epi(source)}/R_{epi(preferred)}$) vs. preferred R_{epi}.

Figures 22-25 describe the influence of event size on the distance uncertainty. Similar to scatter plots presented in the magnitude and depth uncertainty sub-sections the data in these figures are sorted with increasing event size. The distance uncertainty is described as the difference in the computed differences between the preferred and other seismological sources (i.e., $R_{epi(source)}$-$R_{epi(preferred)}$). Regardless of the type of distance metric the scatters in Figures 22-25 loosely point the influence of magnitude on the uncertainty of distance calculations. That is, for smaller magnitude events, the scatter in distance measures is more significant with respect to larger magnitudes ($M_w > 6$). Another interesting observation from these figures is the similarity of observed scatter trends regardless of the type of distance metric. Relatively larger scatter in small magnitude events may also indicate that the variations in fault geometry that is obtained from fault plane solutions do not play a major role in distance uncertainty. The fault geometry as well as the rupture plane that is proportional to earthquake size are more important for the computation of extended-source distance measures for large magnitude events. They are relatively less important as the event size gets smaller since the rupture plane can be mimicked as a point-source for such cases. All of these observations arguably advocate that epicentral coordinates, being the only common metadata parameter in distance calculations, may dominate the uncertainty in source-to-site distance measures.

The above assertion is further investigated by studying the relationship between the R_{epi} and R_{jb} uncertainties. Figure 26 shows the $R_{epi(source)}$-$R_{epi(preferred)}$ vs. $R_{jb(source)}$-$R_{jb(preferred)}$ scatters. Almost one-to-one relationship between these two varieties indicate once again the importance of epicentral coordinate variation, at least, in the calculation of these 2 distance measures as the magnitude parameter is the only additional parameter in the computation of R_{jb} as listed in Table 9.

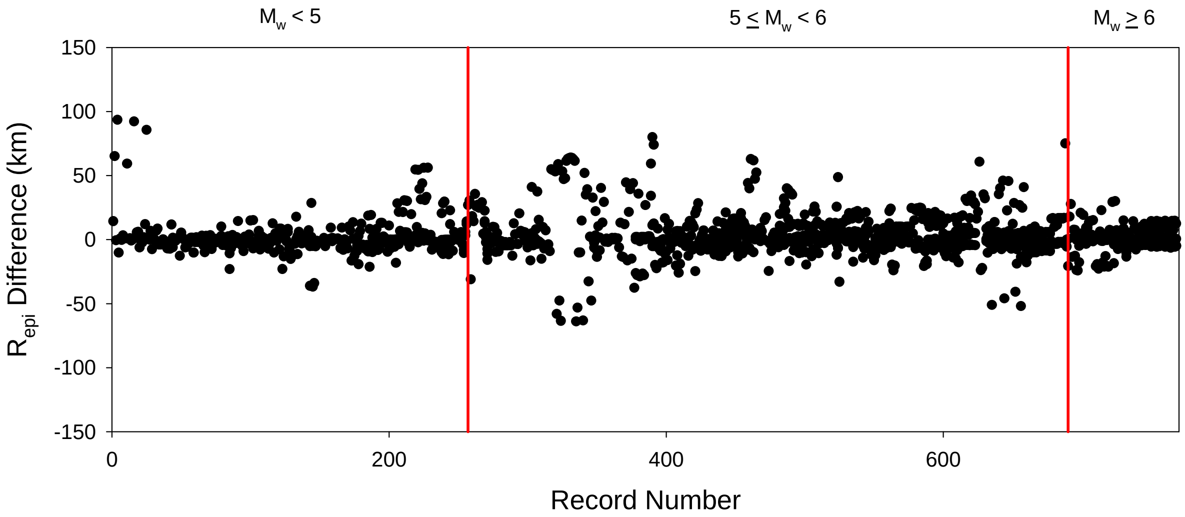

Figure 22. Uncertainty in R_{epi} in terms of increasing M_w.

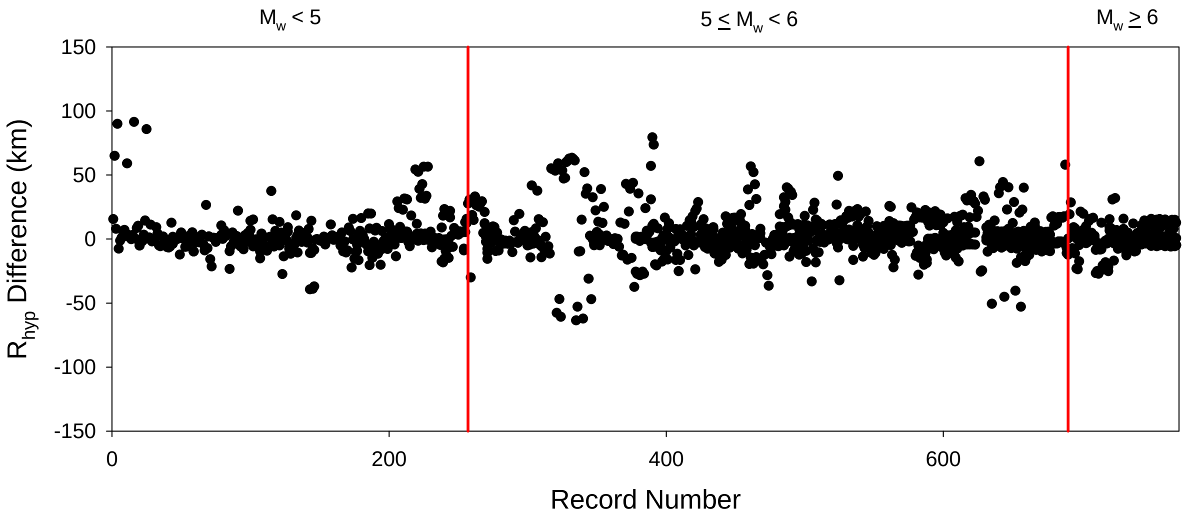

Figure 23. Uncertainty in R_{hyp} in terms of increasing M_w.

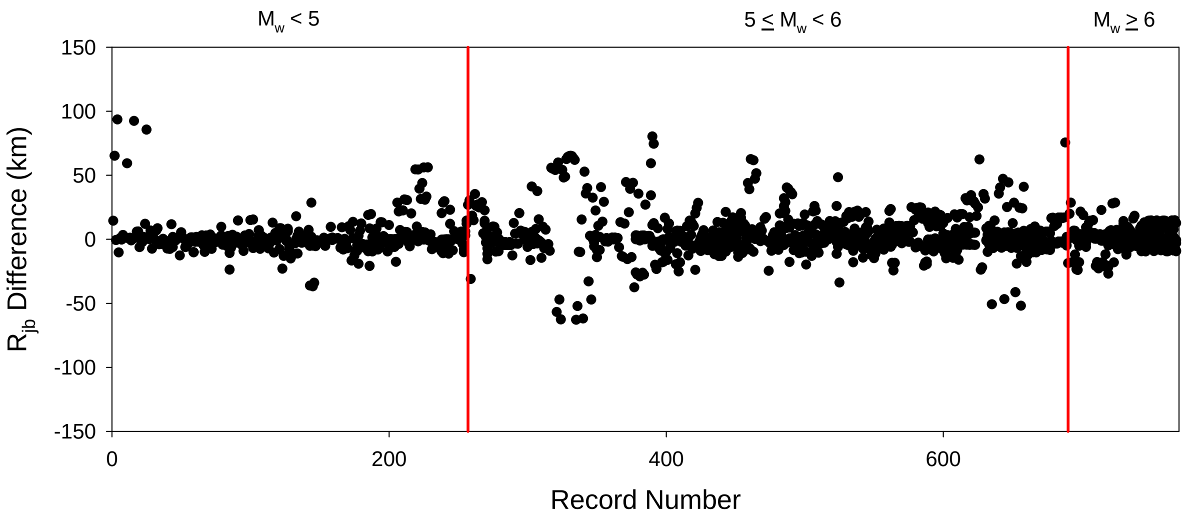

Figure 24. Uncertainty in R_{jb} in terms of increasing M_w.

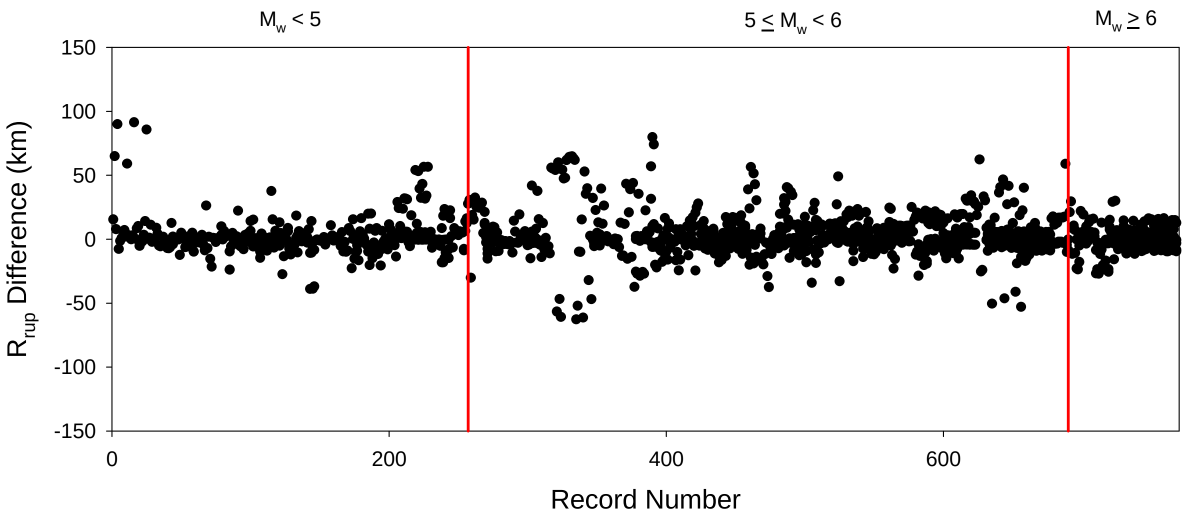

Figure 25. Uncertainty in R_{rup} in terms of increasing M_w.

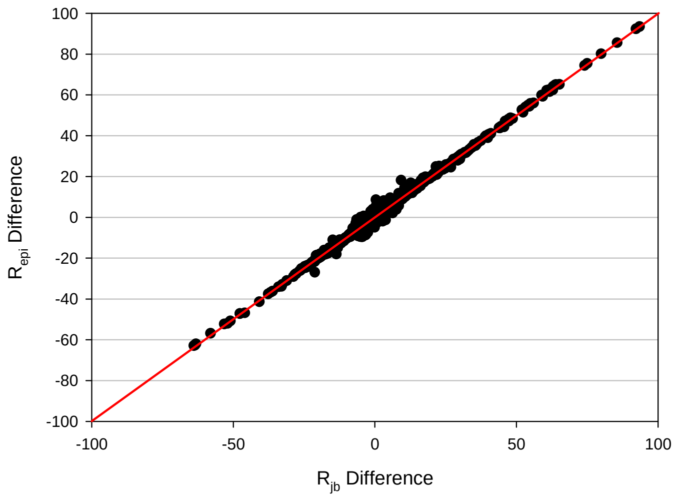

Figure 26. Relation between R_{jb} difference and R_{epi} difference

6. Influence of Metadata Uncertainty on GMPEs

The ground motion prediction equations (GMPEs) mainly model the source and path effects. (The uncertainty in site effects is not considered in this study because the considered database to address the metadata uncertainty, T-NSMP, follows a consistent methodology for in-situ site measurements; MASW as given in Table 7). Each effect is represented by functions of different seismological parameters. The main estimators can be listed as the moment magnitude (M_w), source-to-site distance measures (e.g., R_{JB} or R_{rup}) and style-of-faulting (SoF). For empirical predictive equations the major issues become the size of the database and its metadata features. In order to develop a reliable predictive model the database should be well-constrained in terms of magnitude and distance distribution. Moreover, the uncertainty in the estimator parameters should be as low as possible. For a better distribution of M_w and distance the model developers sometimes integrate data from different seismological sources by applying a hierarchy among these seismological sources to establish an order of preference in gathering the metadata information. The recently compiled databases T-NSMP (Akkar et al., 2010) and SHARE (Yenier et al., 2011) utilize this approach to assemble preferred strong-motion databases (i.e. databases established from a preferred order of metadata parameters). The objective of this section is to see how GMPEs derived from a preferred database differ if the uncertainties associated with magnitude or source-to-site distance parameters are considered in the preferred database. As in the case of previous section T-NSMP will be used to achieve this objective.

The previous section gives the details of uncertainty in each major metadata parameter in T-NSMP. When the magnitude and fault-plane solutions (the most indicative parameters to compute source-to-site distances) are of concern, there are only a few institutions that can fully report these parameters. The study conducted in this chapter is limited to 3 institutions; G-CMT, R-CMT and SED as the other agencies are the only the sources of a few number of events considered in this section. These agencies use their own solution procedures to calculate the important metadata parameters for developing GMPEs. The details about the metadata calculation procedures adopted by each one of these seismological agencies will be given in the next report.

Two different groups of datasets are compiled from T-NSMP to achieve the objectives of this chapter. The first group (G1) is composed of three datasets that are assembled specific to the available data from each of the reference agencies. That is, we use only G-CMT (262 recordings) or R-CMT (164 recordings) or SED (187 recordings) as source of metadata information in each dataset. The detailed description of each subset will be given in the next report. In the second group (G2), the common recordings in G-CMT, R-CMT and SED are extracted (90 recordings). Three databases that use the pertaining metadata of G-CMT, R-CMT and SED are assembled. This group shows the uncertainty for the same recordings but the metadata information given by 3 different agencies; however, the number of the data used in this group is very limited. For each dataset we derived predictive ground-motion equation as described in the following paragraph. We re-established the same datasets from the preferred metadata information of T-NSMP and ran another set of regressions for developing the preferred GMPEs that are used to address the influence of metadata uncertainty on GMPES.

We used the functional form proposed by Akkar and Bommer (2010), [AB10] in this case study because of its simplicity. The functional form includes quadratic magnitude scaling and magnitude dependent distance decay with fictitious depth term. The magnitude and distance terms are functions of M_w and R_{jb}. The SoF effect is not taken into account although it is included in AB10. Two broader site groups are used in the functional form by site dummies for soft (V_{S30} < 360 m/s) and stiff sites (V_{S30}>360 m/s). The mixed-effects regression procedure (Abrahamson and Youngs, 1992) is used to compute the coefficients of the derived equations for each dataset. In order to focus on the major scope in this chapter, the regression coefficients are not given but for two magnitude levels (M_w = 5.5 and M_w =6.5) the normalized PGA curves are plotted in order to compare the influence of the metadata uncertainty in developing GMPEs. The comparative plots are given in Figure 27. The left panel on Figure 27 shows the ratios for M_w = 5.5 and the right panel shows the same ratios for M_w = 6.5. Top and bottom rows show the comparisons for G1and G2, respectively.

Depending on the catalog information, the ground-motion estimations vary considerably with respect to the reference model estimations that are derived using preferred metadata. It is also noted that the discrepancies are more prominent both at larger distances and for larger magnitudes. When we compared the agency based models, G-CMT based model yields relatively closer estimations to the reference model for a limited short distance range with respect to other models derived from R-CMT and SED.

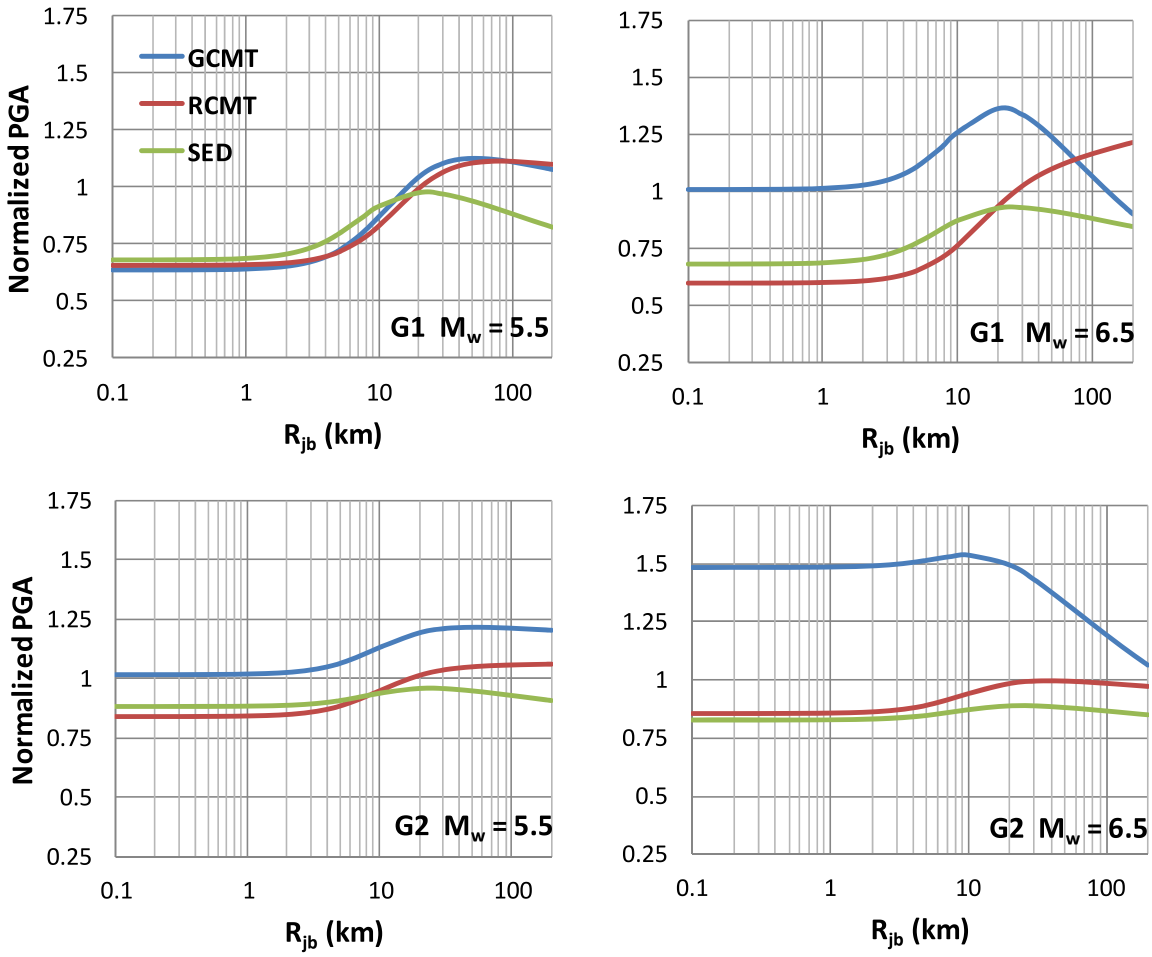

Figure 27. Comparison of the GMPEs developed by using different datasets in order to understand the uncertainty in seismic parameters.

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8. Appendix

Table A.1. List of Agencies Used in the Compilation of Database

Acronyms	Agency
ISC	International Seismological Centre
HRV	Harvard Centroid Moment Tensor
USGS	United States Geological Survey
ANSS	Advanced National Seismic System Catalog Database
ISK	Istanbul Kandilli Observatory and Earthquake Research Institute
GDDA	General Directorate of Disaster Affairs of Turkey
SED	Swiss Seismological Service
RCMT	European Mediterranean Regional Centroid Moment Tensors Database
ESMD	European Strong Motion Database
EMMA	Earthquake Mechanisms of the Mediterranean Area Database
IRIS	Incorporated Research Institutions for Seismology
ATH	National Observatory of Athens, Greece
THE	Geophysical Laboratory, University of Thessaloniki, Greece
HLW	National Research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt
CSS	Cyprus Station – Geological Survey Department, Nicosia, Cyprus
CSEM	European Mediterranean Seismological Center
JER	Jerusalem Station- Geophysical Institute of Israel
PPT	Geophysical Laboratory, Papeete, French Polynesia

Report on "RESORCE seismic motion databank: 2011 version, including the improvement of meta-parameters" by Michel Granet.

A few reminders

The RESORCE project consists in the building of a unified and homogeneous databank for ground-motion at a European level. Let us recall that the most important objective of RESORCE databank is to include only reliable, verified and high quality data and information. The databank is created with the aim of being a reference seismic ground motion database in Europe especially for the development and the test of European ground motion prediction models to be used for seismic hazard studies.

The first step in building RESORCE consisted in extracting data and information from the pan-European data and meta-data subsets of SHARE databank. If the first deliverables recall the main objectives of the work-package, give a detailed and comprehensive view on the future structure of the database and provide a very detailed review of the existing European ground-motion databases, this second report illustrates the progresses made in the last months in the RESORCE strong-motion databank and the main part of the report is devoted to describe the strategy implemented to surmount the inconsistencies observed in source-to-site distance measures from different sources.

Current state of the databank

At this time, the RESORCE databank consists in 5 115 strong motion recordings from 1 685 earthquakes. Some events were rejected from the former version because they fail to contain the most significant metadata parameters. I have not found in the document the total number of stations having recorded the retained events in the databank. The metadata of the current version of the databank include information on earthquake, station and waveform. The document provides the major reference sources in the RESORCE databank (table 1). Even if the report indicates that the next version will include RAP French data and Swiss data, this is still surprising to not include, at least partly, some of them at this step (for example, for some large earthquakes which occurred in Western Europe). Part of this information is extracted from the literature.

Also, the report gives some statistical analysis about the current content of the databank:

- The number of data versus year (figure 1): the data cover the 1972-2009 period;
- The list of originating countries for earthquakes is given in table 2: 67% of the records come from Turkey and Italy;
- The magnitude distribution (figure 2): number of events versus Mw for both events and records. These Mw are issued for some of the recordings from empirical magnitude relationships (867 from Turkey and 260 from Italy); however, I count that there are at least 200 recordings having an "unknown" Mw;
- The event and recording distribution in terms of focal depths: more than 70% of the events are characterized by a focal depth less than 10km.

A significant effort has been made to homogenize the style-of-faulting (SoF) and the document provides the implemented criteria for this process. Globally, strike-slip and normal events are largely dominant while close to 30% have an unknown SoF.

In its current version, the RESORCE databank contains a total of 441 strong-motion stations with known VS30 values (for 2 838 accelerograms). Table 7 gives the methods for Vs measurements. 350

site classes are inferred from the geological conditions. 21% of the total number of recordings does not have any information about soil classification.

One of the main improvements in this current version concerns the source to site distance measures. It concerns the following distances: “Repi” (epicentral distance), “Rhyp” (hypocentral distance), “Rjb” (Joyner-Boore distance is defined as the closest distance from a site to the surface projection of the fault rupture) and “Rrup” (the closest distance to rupture). In fact, the initial SHARE databank - from which RESORCE originated initially - contains inconsistencies within some distance information and the distances for which these inconsistencies were detected have been recomputed. A set of rules is applied to recomputed if necessary Rhyp, Rjb and Rrup distances (Repi is taken directly from the initial reference database). The process considers different cases: i) when the true fault-plane solution is known; ii) when double-couple fault plane solutions are provided without identifying the true fault plane; iii) when double-couple fault plane solutions are not provided. The results are illustrated in figure 7 which shows the relationships between different distance measures. This clearly demonstrates that initial inconsistencies have been largely removed.

A last chapter of the report discusses the RESORCE use and perspectives. The databank will be freely accessible with the possibility to identify all data providers. It is proposed to frozen each version of the RESORCE databank (accessible on the net). The content of the databank will be improved and updated during the SIGMA life. The back end for this database will use the PostGresql Database and will be accessible by a web user interface in a web browser. It is also planned to fulfill the coding standards which requires establishing the uniqueness of the pair “operator-station”. This needs to collect the station codes used by each operator and to include them in the metadata file.

Appendix A presents the parameter inconsistencies observed during the implementation RESORCE databank. This is illustrated by some figures. It concerns the epicenter longitude, the epicenter latitude, the depth of earthquakes, the magnitude (see above), the source-to-site distance measures.

Appendix B presents a text to be included on the RESORCE data access and distribution web page.

Appendix C gives the structure and content description of the RESORCE databank, version 2011.

In conclusion,

- This SIGMA WG has well progressing and its development fits the specifications.
- The current version of the "RESORCE" databank integrates an important work in order to remove some inconsistencies detected when extracting the data from the initial databases; in addition, some missing data have been added.
- The current version still contains some gaps (e.g.: magnitude is not provided for all events, soil classification): is it envisaged to address them and if so how?
- The database is still limited in terms of number of earthquakes and originating countries. There is the issue of the integration of French and Swiss accelerograms: what is the strategy planned for this integration? And what are the data concerned: all of them or only those concerning a set of earthquakes?

Michel Granet, 12 November 2011.