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A harmonized seismicity data base for the Euro-Mediterranean region

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Abstract

Data from over 50 domestic and regional catalogues, the ISC and NEIC bulletins for the NE Atlantic Ocean, and numerous special studies were used to compile an M_w based earthquake data base for Europe and the Mediterranean region. Non-tectonic, non-seismic and non-existing as well as duplicate events were identified and removed according to our current stage of knowledge. If not given by the original source, M_w was calculated for each event with a specified epicentral location and a given strength measure (i.e., a magnitude of any type or, for onshore events only, an intensity). The investigated area is subdivided into 37 polygons, in each of which one or more catalogues, supplemented by data from the special studies, are used. If more than one catalogue lists an event, one entry was selected according to a priority algorithm specific for each polygon. If the selected catalogue entry contains more than one strength type, one was selected for the M_w calculation according to another priority scheme. A current version of the data base, with events mainly in the area north of latitude 44°N, in the time period 1000-2004, and with magnitudes $M_w \geq 3.50$, has recently been released as the CENEC catalogue (*Grünthal et al.*, 2009b) and its harmonization with respect to M_w has been investigated (*Grünthal et al.*, 2009a). Besides updating this part, an extension to southern Europe and the Mediterranean region is under construction, with a higher threshold magnitude foreseen for the southern part.

Introduction

Earthquakes have caused many major disasters in Europe. The two worst in the past centuries occurred offshore Lisbon in 1755 and in the Strait of Messina in 1908 and caused about 70,000 and 72,000 deaths, respectively, to a large extent by the generated tsunami waves. Including the area immediately to the east of the Mediterranean Sea, the Aleppo earthquake in 1138 with estimated 130,000 fatalities should be noted. An earthquake the year after in Azerbaijan just off the SE corner of Europe caused an estimated 230,000 deaths. Figure 1 shows the earthquakes in the current data base with M_w magnitudes of 6 and larger, with the most destructive events marked (Table 1). Events with $M_w \geq 8$ are given in Table 2.

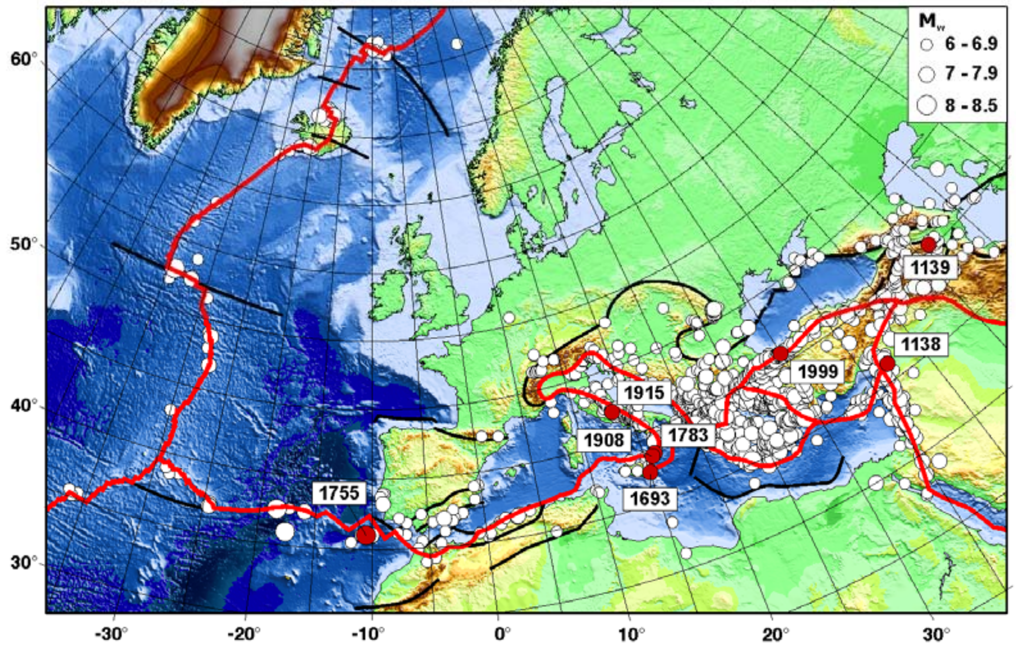

Figure 1. Earthquakes in the data base with $M_w \geq 6$. The most destructive earthquakes are specially marked (see Table 1). The plate boundaries are after *Bird* (2003), modified and extended by the authors.

Table 1. The most destructive earthquakes in the Euro-Med region (number of fatalities).

Date	M_w	Country	Location	Fatalities[1)]
1138 October 11	7.1	Syria	Azrab/Aleppo	130,000
1139 September 30	7.7	Azerbaijan	Ganzak	230,000
1693 January 11	7.4	Italy	Catania	60,000
1755 November 1	8.5	Portugal	Lisbon	70,000
1783 February 5	6.9	Italy	Calabria	35,000
1908 December 28	7.1	Italy	Messina	72,000[2)]
1915 January 13	7.0	Italy	Avezzano	35,000
1999 August 17	7.5	Turkey	Kocaeli	45,000[3)]

[1)] After *Musson* (2001) and *Marza et al.* (2003) except 1908

[2)] Numbers in the literature ranges from 60,000 to 200,000, the more reliable from 65,000 to 110,000; the preferred number, 72,000, is given by *USGS* (2009)

[3)] Sum of reported killed (20,000) and missing (25,000) (*Marza et al.*, 2003)

Table 2. Earthquakes with $M_w \geq 8$ in the Euro-Med region.

Date	M_w	Epicentre
365 July 21	8.3	offshore Crete
1303 August 8	8.0	offshore Rhodes
1755 November 1	8.5	offshore Lisbon
1939 December 26	8.0	Erzincan, Turkey
1941 November 25	8.3	Gloria fault, Atlantic Ocean
1967 February 13	8.2	North Atlantic Ridge
1975 May 26	8.1	Gloria fault, Atlantic Ocean

Because strong events in the investigated area are scarce, the entire damaging potential can only be understood when long time spans are considered. It is a requirement from various current EU and other projects to have high-quality, harmonized earthquake catalogues extended over a long period of time. The existing global and European data bases such as ISS/ISC, NEIC, *Engdahl et al.* (1998), BCIS/EMSC or *Kárník* (1996) are covering too short time periods and/or have too high threshold magnitudes to be satisfactory, especially in areas of relatively low seismicity such as large parts of Europe. The magnitudes are also not unified in some of these data bases. It is the objective of the current study to create a homogeneous catalogue for Europe and the Mediterranean region.

Tectonically, the study area corresponds to the whole western part of the Eurasian plate, including the adjoining micro-plates, and the corresponding plate boundary zones in the Atlantic Ocean, the Mediterranean region, and the eastward extension of the complicated southern bounds of the Eurasian plate running through the Caucasus and the Caspian Sea.

Data and method

Our data base is founded on over 50 local or national catalogues and data bases, and numerous special studies on individual events, event series or regions. They represent, in most cases, the optimal completeness of events and precision of their parameters, and together they cover the historical and instrumental time periods of the investigated region. Currently (June 2009), there are over 450,000 entries in the total data base, whereby an event can be represented by entries from several sources The entries are then lumped together to form a family for this event.

The investigated area is defined by and subdivided into 37 polygons (Fig. 2). The border of these mostly follow the national borders. For each polygon, one or more local catalogues and data bases are accepted as sources from which the representative entry for an event is selected. If there are entries from more than one of the allowed catalogues, a specified hierarchy decides which one to use. Data are also provided by many special studies referring to one or a limited set of events. These data usually have priority over the local catalogues as to picking the preferred entry.

All original data which do not have M_w but another magnitude concept and/or intensity were assigned M_w through conversion algorithms. An error estimate is given for each derived relation by *Grünthal et al.* (2009b). The regressions for the M_w conversion formulae were carried out using the chi-square maximum likelihood technique described by *Stromeyer et al.* (2004). For each catalogue, a priority scheme decides from what other strength measure M_w should be calculated. Where an M_w entry is given by *Swiss Moment Tensor Solutions* (2009) or *Pondrelli et al.* (2002, 2004, 2007), which are sources providing original M_w from digital data, this was used.

So far a full analysis has been performed and published for the northern part of the Euro-Med region, i.e., basically north of latitude 44°N, the CENEC catalogue (CEntral, Northern and northwestern European earthquake Catalogue, *Grünthal et al.*, 2009b).

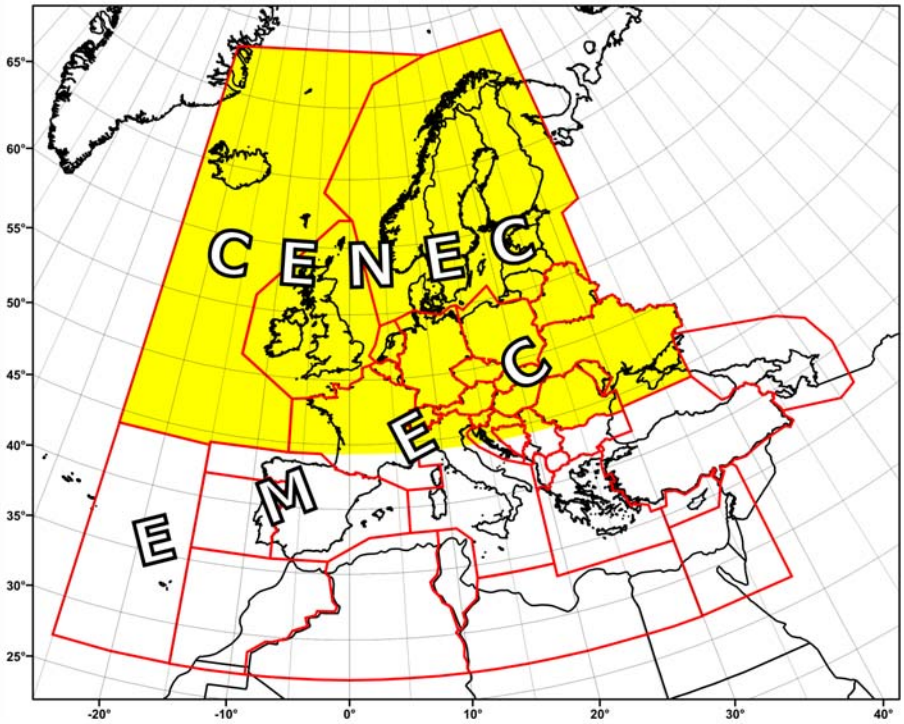

Figure 2. The polygons in each of which one or more of the catalogues and data bases is valid. The EMEC catalogue encompasses all polygons; CENEC covers the yellow-marked area.

This study gives details on the local catalogues, polygons, and the different priority rules. The work continues with the southern part and with updates of the northern part to an extended catalogue, EMEC (Euro-Mediterranean Earthquake Catalogue), covering the whole Euro-Med region.

Harmonization of M_w (CENEC part)

Even if all entries get M_w, it remains to investigate how compatible they are to each other. This has so far been done for the CENEC entries (*Grünthal et al.*, 2009a). Some inhomogeneity in the M_w obtained from over 40 local catalogues and data files and over 50 special studies is inevitable.

Only about 2% of the data used for CENEC have original M_w magnitudes derived directly from digital data (most of them from the sources mentioned in the previous section). Some of the local catalogues and data files give M_w, but calculated by the respective agency from other strength measures. About 60% of the local data give strength measures other than M_w and these are the ones we have converted.

Two different approaches have been followed to investigate the compatibility of the different M_w sets. The first approach compares original M_w from *Swiss Moment Tensor Solutions* (2009) and *Pondrelli et al.* (2002, 2004, 2007) with (1) M_w given in national catalogues and (2) M_w derived by applying different empirical relations developed for CENEC. These high-quality M_w data bases specialize on European and Mediterranean area events. The second approach concerns the vast majority of earthquakes in CENEC,

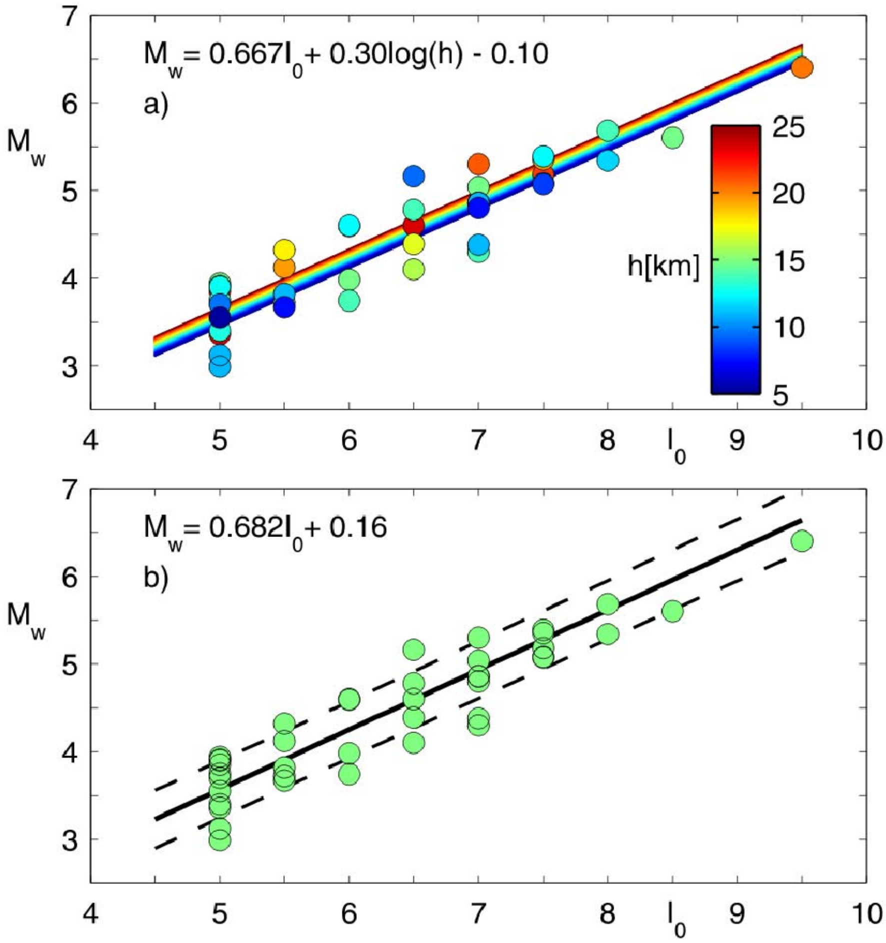

Figure 3. Master event relations and the 41 data points used for their derivation (after *Grünthal et al.*, 2009a). **a** depth-dependent relation and **b** depth-independent relation. The dashed lines in **b** show the 68% confidence bounds, whereas the confidence bounds in **a** cannot be visualized in a simple way.

for which no digitally obtained M_w exist. In this case, an empirical relation for the M_w dependence on epicentral intensity (I_0) and focal depth (h) was derived for 41 master events with high-quality data and located all over central Europe (Fig. 3a). To include also the data lacking h, the corresponding depth independent relation for these 41 events was also derived (Fig. 3b). These equations were compared with the different sets of data from which CENEC is composed and the goodness of fit was calculated for each set. The vast majority of the events are very well or reasonably consistent with the equations so that the data can be said to be harmonized with respect to M_w, but there are exceptions, which are discussed in detail *by Grünthal et al.* (2009a). In the ongoing study, covering also southern Europe and the Mediterranean region, harmonization checks will be used to improve existing M_w calculating algorithms, striving at a maximum harmonized catalogue.

Conclusions

It is a long and non-trivial work to compile, edit, scrutinize, and homogenize all the data in the large data base and to make the final selection of the entries for the catalogues. An important part of the study considers the identification of duplications and various types of fake events. False locations and dates, and non-tectonic and non-seismic events, were labelled as such and eliminated from the further analysis.

A critical part of any data base compiled from different local sources is the harmonization of magnitudes. The present one contains unified M_w magnitudes, but a full harmonization is hard to achieve. Different quantitative tests showed that a high degree of harmonization exists for M_w from most local catalogues and data bases, but there are a few notable exceptions. The need for such tests as a part of cataloguing work is urgent, although usually not made.

Fig. 1 shows the excellent correlation of the major seismicity with the plate boundaries and main faults. The intense seismicity in Greece, western Turkey, and Caucasus is connected with the complicated plate - sub-plate pattern. The data base presented here gives more complete and constrained solutions than those presented by the international seismological centres, and it has the added benefit of including historical data. In our data base, parameters from ISC and NEIC provide preferred entries only where a domestic catalogue does not exist, i.e., for Atlantic Ocean events.

Quality data of this kind are important to adequately quantify the seismic and tsunami threats. The historical data show that even if catastrophic events are infrequent these threats must be taken seriously,

The CENEC catalogue and the extended catalogue, EMEC, will be useful for applications in many fields of seismicity and in seismic hazard assessment, especially in large-scale projects of probabilistic seismic hazard assessment.

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