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Reply to comment by Günter Leydecker on “The European–Mediterranean Earthquake Catalogue (EMEC) for the last millennium”

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In the comment on Grünthal and Wahlström (2012), reference in the following as G&W12, Leydecker (2013) refers to German sources which were not used in the European–Mediterranean earthquake catalogue EMEC (G&W12). He points out that basically the earthquake catalogue Leydecker (2011) should have been used as well as earlier versions announced and being accessible from the website of the Federal Institute for Geosciences and Natural Resources (BGR).

We have received the Leydecker (2011) catalogue a few weeks before we submitted the manuscript of G&W12. We have, of course, made a quick check of this catalogue. It revealed that we, in fact, do not miss any earthquake within Germany from this source in EMEC, with its magnitude threshold $M_w = 3.5$, apart from events which are proven to be fakes or induced seismic events, which are not part of EMEC. There are also events where the interpretations (time, location or strength) by Leydecker (2011) and by G&W12 differ. Thus, as there are no relevant earthquake entries in Germany in Leydecker (2011) which required addition to EMEC, we have not referred to this catalogue. In the following paragraphs, we provide examples and details implicating why the Leydecker (2011) catalogue was not considered.

1 Historical fake earthquakes

Already 23 out of the first 37 “tectonic earthquakes” in Leydecker (2011, printed version with $I_0 \geq IV$) are proven to be fakes, i.e. in the period from the year 813, when the catalogue starts, up to 1350. This high portion of fakes could have been reduced, if our previous catalogue CENEC (Grünthal et al. 2009) or Grünthal (2004) with the list or summary of fakes therein had been consulted.

Leydecker (2013) highlights that the event “1391-0323 ... in N-Switzerland” is a fake. The fact is that a poorly known earthquake occurred in the region in the first half of the last decade of the fourteenth century. The earliest source of this event which could be used by Schwarz-Zanetti and Fäh (2011) is a near-contemporary chronicle from Zurich which was written in 1438 (edited by Dierauer 1900) and based on a lost earlier source from 1415. The erroneous double dating in the earliest known source (1394-03-22, on a Wednesday of the Easter week, i.e. the week after Easter) is in contradiction with March 22 of this year - for details, see Schwarz-Zanetti and Fäh (2011). This caveat found different interpretations with respect to this date in the secondary literature; besides 1391-03-22 (in this year, March 22nd was on the Wednesday before Easter), also 1391-03-23, 1394-03-22, 1394-04-22. The latter date is the preferred one by Schwarz-Zanetti and Fäh (2011). Here, the Wednesday of the Easter week is a 22nd. This interpretation dates back to corrections from the fifteenth century in two transcripts of the earliest source. It was used in the

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Swiss earthquake catalogue ECOS-09 (Fäh et al. 2011) and is adopted now by us as well.

2 Disregarded and induced seismic events (examples)

Two earthquakes in Leydecker (2011) within Germany were not included in EMEC for reasons, described as follows:

For the earthquake 1674–11 with $I_0 = V-VI$ in Leydecker (2011), which yields an $M_w > 3.5$, at $50.7^\circ N$ and $13.7^\circ E$ (actually in the Czech Republic, a couple of kilometres south of the German border), it is known after Lehmann (1699) that mining collapses occurred especially in Breitenbrunn ($50.47^\circ N$, $12.76^\circ E$) where a miner died. This event is certainly non-tectonic. Besides, aboveground macroseismic effects, also during an earthquake swarm in the second half of November 1647 without any areal specification of a location in the region of the Ore Mountains, did not exceed intensities IV–V, i.e. $M_w < 3.5$, below the threshold of EMEC.

The earthquake 1949-06-30 with $I_0 = IV-V$, $M_L = 3.8$ in the Lower Rhine embayment with the reference to the Royal Netherlands Meteorological Institute (KNMI) can be traced back to Schwarzbach (1950) and to Houtgast (1992). Both mention roughly the area where it was felt and the epicentral or maximum intensity $I_{max} = IV-V$ but they do not mention a location and a magnitude. After Schwarzbach (1950), it was instrumentally recorded only at the Dutch seismic station Heerlen located at 13 km distance from the epicentre given in Leydecker (2011). According to the contemporary source and the earlier Dutch source, this earthquake also relates to an $M_w < 3.5$.

Outside of Germany, Leydecker (2011) has some more events which are not in EMEC. Also for these, an explanation exists in all cases. Most of them are doubtful events which are not mentioned by the latest domestic catalogues according to the hierarchy used in EMEC, or the magnitude by modern sources is below the threshold.

Examples of mining-induced seismic events which Leydecker (2011) includes as tectonic earthquakes are as follows:

1977-03-24, 7 h 32 min with $I_0 = V-VI$, $M_L = 3.8$ in Poland. This is a well-known mining-induced seismic event of Legnica/Głogów (Lubin), $M_w = 4.1$, with a location by Leydecker (2011) some 50 km SW of the true location, although the reference of Leydecker's source (Kárník et al. 1981) gives correct information on this mining event.

2005-07-13, 3 h 59 min, $M_L = 3.7$, $h = 1$ km, again in the Legnica/Głogów (Poland) mining district. He refers to the "Data Catalogue of Earthquakes in Germany and Adjacent Areas" of the BGR, where it, however, is correctly characterised as "known induced event".

3 German seismicity data from 1994 onwards

We do not know of any "frozen" earlier version of Leydecker (2011) on the web and therefore cannot argue, when which version was present. In the 1990s, Günter Leydecker kindly provided data to us on several diskettes, which for us have the status of "frozen" versions. The one we refer to in G&W12, i.e. Leydecker (1996), includes the historical time and instrumental recordings up to 1994. Together with the Leydecker (1986) catalogue, these data have been used in EMEC up to 1993. Unfortunately, we have referred incorrectly to Leydecker (1996) in G&W12 where information on the format of data entered to the reference. Admittedly, this information on the format is irrelevant and confusing. The reference is correctly given in Grünthal et al. (2009) and in the reference list below.

For modern times, i.e. since 1994, G&W12 use the monthly "Data Catalogues of Earthquakes in Germany and Adjacent Areas" of the BGR, which usually are available with a delay of about two months only. The data for $M_L > 2$ in Germany and adjacent areas are not only based on the more than 150 seismograph stations within Germany but also on those of the neighbouring countries. We feel comfortable to use this database, which, different to the earlier versions of Leydecker (2011), is permanently available on the website of the BGR since 1995. Leydecker (2011) has expanded this database by adding, often uncritically, interpretations of events from other seismological networks, e.g.

data from the International Seismological Centre (ISC). All checks we have made of such additional events so far turned out to show erroneous locations. When residuals of more than 10 s for the nearest stations are reported by the ISC, this should be alarming. That the modern data for Germany from 1994 and on only sporadically provide intensity data, as mentioned in Leydecker (2013), has no relevance for EMEC, since this data file uses harmonised moment magnitudes M_w throughout. The calculation of M_w follows a strict hierarchy with intensity-based determinations last in rank.

4 Concluding remarks

The comparison between the data of Leydecker (2011) and EMEC (G&W12) can also be made vice versa, i.e. with respect to events which are included in EMEC and not given by Leydecker (2011). This comparison reveals that especially many earthquake entries of modern and well-edited catalogues as well as of special studies are missing in Leydecker (2011). These are more than 150 events in his study area 47–56°N and 5–16°E, mostly outside of Germany.

We fundamentally agree with Leydecker (2013) that errors and inconsistencies are hardly avoidable in catalogue works covering large regions and time spans. In summary, however, only a few events in Leydecker (2011) are missing in EMEC and for well-motivated reasons in all cases. The matters of an imprecise reference (Leydecker 1996) and of a fake event outside Germany (1391-03-23) in EMEC could be clarified. The implicated defectiveness of EMEC in the concluding remarks by Leydecker (2013) could thus be firmly disproved. On the other hand, deficiencies in Leydecker (2011), especially the contamination by plenty of fakes, at least for the first 550 catalogue years, and repeatedly un-flagged non-tectonic seismic events, could be demonstrated.

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