Solid Earth Discussions

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Reply on RC3

Thierry Camelbeeck et al.

Author comment on "The damaging character of shallow 20th century earthquakes in the Hainaut coal area (Belgium)" by Thierry Camelbeeck et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-74-AC3, 2021

Dear Gianluca Valensise,

Thank you very much for your positive and very valuable remarks on our paper on the damage impact of the Hainaut seismicity. Here below, we give a detailed reply to your comments and how your input impacts the revised version of the paper. We hope this discussion meets your expectations.

Kind regards
Thierry Camelbeeck for the authors

This review comes after two accurate anonymous reviews which already addressed most of the questions I intended to raise. I will briefly recall my main points. The paper is important and timely, but it is indeed quite long. It looks more like a catalogue, or a technical report, rather than like a scientific paper that extracts something relevant from the data presented. I praise the reviewers' recommendation to move the description of individual events into the Supplementary Materials section, so that the reader is free to focus on the most relevant conclusions of the work.

Thank you for this comment. We kindly refer to our replies to Reviewers 1 and 2 in which we explain how we shortened the paper. Whole section 4 (detailed description of the stronger earthquakes) moved to appendix B.

But I don't want the authors to get me wrong. I think their work is valuable for two independent reasons: for their effort to reorganize the historical seismicity data in a systematic and objective fashion, and for their attempt to use the new data to improve SHA estimates for Belgium. As a matter of fact, I would urge the authors to consider using the data presented in this work to turn the simple parametric catalogue they run on the ROB website into a fully analytical catalogue such as Italy's Catalogue of Strong Earthquakes (http://storing.ingv.it/cfti/cfti5/#). This would be the best way to make sure that their efforts at investigating old earthquakes live over time.

Thank you for the comment and the link to Italy's Catalogue of Strong Earthquakes. This is an amazing and valuable website! It will require some efforts from our side to mimic this website and prepare all our data in QuakeML and its extended version including all macroseismic data, but we will definitely take this comment with us in the future. In the meantime, many of the historical events in Belgium and surrounding areas and their macroseismic dataset are

already made available on the ROB seismicity website and in AHEAD for pre-1900 earthquakes (if a scientific work on the event was published). We hope this will also be the case for the Hainaut part of the ROB catalogue.

The paper is made even longer by the particular wording adopted by the authors. The English is generally good and correct and I have no complaints (although I also noticed a few cases where the authors use single words/expressions that do not really mean what they have in mind: perhaps they are "false friends"?). I am not a native English speaker myself, but I am convinced that adopting a lighter prose and getting rid of some unnecessary explanations might reduce the total length of the text by 10-20%, in addition to reorganizing the text as detailed above.
Yes, you are right. In the first version, some long sentences and explanations were written. In the meantime, and thanks to the comments of all three reviewers, we re-edited the paper entirely, rephrased many sentences and removed some paragraphs with duplications.

All in all, the paper is an important contribution both to the homogenization and reappraisal of historical seismicity data for Belgium and to the quantification of regional seismic hazard, and it certainly deserves to be published on Solid Earth. Nevertheless, I do agree with one of the reviewers who stated that the paper should discuss in better detail the SHA implications of the new findings. I will be more specific in the specific comments listed below.
Thank you again for these kind comments. As explained in our reply to reviewer 2, in the new version of the paper we now highlight the impact of our findings towards SHA much more in the abstract, introduction, discussion and conclusions. We show this in your specific comments in below.

Specific comments
Line 24 - " Hence, because of their shallow sources, moderate SCR earthquakes with magnitudes in the range of 4.0 to 6.0 are often more damaging in SCR than at plate boundaries". I don't share this view. In Italian volcanic areas such as Mt. Etna and the Ischia Island, which certainly do not lie within a SCR, M 4.0 earthquake are capable of causing substantial damage and casualties.
We based this assumption on a statistical analysis that the percentage of shallow earthquakes is higher in SCR than at plate boundaries. Of course, this does not mean that shallow M=4.0 earthquakes cannot occur at plate boundaries or would not cause damage. Following your comment, we deleted the first sentence of in introduction to which you referred above, and modified the text in the abstract and in the introduction as follows:
"Moderate shallow earthquakes with magnitudes in the range of 4.0 to 6.0 have a real potential of destruction when they occur in populated areas. This is particularly the case in regions where the building stock is old and vulnerable, and contains few earthquake-resistant buildings. In seismically active regions, even if 4.0 MW earthquakes can be locally damaging (Nappi et al., 2021), current hazard is associated with the upper part of this magnitude range…"

Line 163 - "However, as the earthquake occurred at midnight, there was no notice of the event outside a radius of 3 to 4 km from the barycentre of all macroseismic data points". I don' t understand this. What difference does it make if the earthquake occurred at night or during the day? It was felt over a small area because it was shallow, regardless of the time of the day.
The reason why we wrote this sentence is that at a larger distance many people were sleeping and were not awakened by the earthquake. This leads to a lack of observations in these areas where you normally would have observed effects associated to intensities II to IV during the daytime. Hence, it was not possible to evaluate the real extension of the macroseismic field. We modified the text to

take this remark into account.

Line 168 - "Two months later, the earth shook again north of Charleroi, but more strongly with a MW =3.9 event on 1 June at 22h51m... The epicentral area of the 1 June 1911 earthquake includes the localities of Gosselies, Lambusart and Ransart where the tremors were violent enough to awaken most of the inhabitants, knocking down many chimneys and causing cracks...". The authors should compare this event and its effect with those of the 27 August 2017, Ischia earthquake, a Mw 3.9/ Md 4.0 event located around 1 km depth.
Thank you for your suggestion. In the new version of the paper, we compare the Hainaut attenuation model and earthquake effects with macroseismic data of other shallow earthquakes to demonstrate how fast the Hainaut model is (see our detailed reply to reviewer 1 and figures in supplement). We deliberately chose to compare the attenuation with Mw 4.0 events from Oklahoma, as these events are recurrent and many data points are provided to make a statistical correct attenuation. These events occur in a similar intraplate tectonic context as the Hainaut seismicity. We believe that adding a comparison with a volcanic context might confuse the reader so we decided not to add the intensity data points of the Ischia earthquake to our comparison.

Line 172 - "...the most affected locality was Ransart where more or less 50 chimneys collapsed and a parked train was thrown off the tracks... We assessed intensity to VI in Ransart ...". Are you extra sure of this statement? Seems to me that overturning a train would require accelerations that are incompatible with the size of this quake, even if it occurred at very shallow depth. And an intensity VI sounds very low for such a damage scenario.
The train that was derailed from the tracks was a smaller mine train used by the mining industry. It is difficult to evaluate the stability of such a vehicle on a small mine rail inside an industrial field. The observation suggests local high accelerations that would likely correspond to an intensity higher than VI, but there is no description of building damage for a mean intensity greater than VI in Ransart. We also clarified in the discussion that the spatial resolution of our intensity data is too low to identify very local intensity effects [see section 6.3].

To take this comment into account, we slightly changed the wording in appendix B to:
...and a parked mine train was derailed from the tracks.

L*ine 322 - "The last earthquake in the Hainaut coal area for which it was possible to provide a macroseismic map occurred near Carnières on 14 September 1982 at 19h24 (MW =3.4; Fig. S28). Two earthquakes were also widely felt in the region of Charleroi on 4 and 9 August 1983...". It sounds like no more earthquakes occurred after 1983? Is that really so? The authors mention something about it in this very long paper, but this point should be made very clear if we are to discuss the crucial issue of the natural vs. induced/triggered origin of this seismicity.*
After these 1983 earthquakes, the largest events that occurred in Hainaut are three ML=2.5 earthquakes, which were weakly felt. Earthquakes of magnitude below 2.0 occurred from time to time (31 earthquakes during the last 20 years), meaning that very little seismic energy was released in the coal mining area after 1985. We added this sentence at the end of Section 2 - Earthquake Catalogue. This seismicity is further discussed in Section 6.4 - Focal depth determination.

Line 410 - " Figure 10 reports the influence of focal depth from 1.0 to 6.0 km on the intensity attenuation curves and its stronger effect on the attenuation function than the uncertainties on the attenuation parameters. This also suggests that earthquake focal

depth can be evaluated with a good accuracy using IDPs and that the differences in attenuation observed between the different earthquakes in the modelling (Fig. 9a) would likely reflect the small differences in their respective focal depths." I totally agree with this statement based on the authors' own data and based on my own experience. It is a strong conclusion that should be elucidated more extensively in the discussion.
Thank you for your suggestion to highlight this strong conclusion of our research even more! In the meantime, we completely rewrote the abstract to clarify all the findings and implications of our work based on the suggestions of the three reviewers. In the abstract we added the conclusion you suggested above. The current abstract reads as follows:
[The present study analyses the impact and damage of shallow seismic activity that occurred from the end of the 19th century until the late 20th century in the coal area of the Hainaut province in Belgium. This seismicity is the second largest source of seismic hazard in northwestern Europe, after the Lower Rhine Embayment. During this period, five earthquakes with moment magnitudes (MW) around 4.0 locally caused widespread moderate damage to buildings corresponding to maximum intensity VII in the EMS-98 scale. Reviewing intensity data from the official macroseismic surveys held by the Royal Observatory of Belgium, press reports, and contemporary scientific studies resulted in a comprehensive macroseismic intensity data set. Based on this data set, we created macroseismic maps for 28 earthquakes, and established a new Hainaut intensity attenuation model and a relationship linking magnitude, epicentral intensity and focal depth. Using these relationships, we estimated the location and magnitude of pre-1985 earthquakes that occurred prior to deployment of the modern digital Belgian Seismic network, resulting in a new updated earthquake catalogue for the Hainaut area for this period including 124 events. A comparison with other areas worldwide where currently similar shallow earthquake activity occurs, suggests that intensity attenuation is strong in Hainaut. This high attenuation and our analysis of the cumulative effect of the Hainaut seismicity indi-cate that current hazard maps overestimate ground motions in the Hainaut area. This reveals the need to use more appropriate ground motion models in hazard issues. Another strong implication for earthquake hazard comes from the reliability of the computed focal depths that helps clarifying the hypotheses about the origin of this seismicity. Some events were very shallow and occurred near the surface up to a depth not exceeding 1 km, suggesting a close link to mining activities. Many events,including the largest shallow events in the coal area before 1970, occurred at depths greater than 2 km, which would exclude a direct relationship with mining, but still might imply a triggering causality. A similar causality can also be questioned for other events that occurred just outside of the coal area since the end of the mining works.]

Line 416 - I believe that Fig. 10 should be 11.
No, this was correct. (now Fig. 6 in the paper).

Line 492 - " The most destructive events occurred during or at the end of the mining exploitation." Once again, this is a crucial observation concerning the natural vs. induced nature of local seismicity. As such it should be more emphasized.
See our reply to line 322 and the last part of the rewritten abstract.

Line 518 - " All these observations suggest that the contribution of the Hainaut coal area seismicity on current seismic hazard maps in Belgium and northern France (Fig. 1) could be overestimated inside but especially outside the basin and would need to be reevaluated." This is a strong conclusion, hence I recommend the authors to clarify what exactly causes this overestimation.
Thank you for pointing us towards this confusion in the text. We clarified this

part of this section and end the paragraph now with:
[These observations suggest that the contribution of the Hainaut coal area seismicity to the impact of earthquake activity in southern Belgium and northern France (Fig. 1 was overestimated by comparison to consequences of other seismic sources outside the Hainaut area.]

Furthermore, as you suggested, we repeat this strong conclusion in the Section 7 - Conclusions as follows:
[Our analysis suggests that the contribution of the Hainaut coal area seismicity on current seismic hazard maps in Belgium and northern France (Fig. 1) are overestimated and need re-evaluation, on the one hand because the magnitude of the largest events have been downsized in our new catalogue and, on the other hand, because the seismic energy is rapidly absorbed within the Hainaut coal basin due to the strong attenuation. This conclusion provides new perspectives for seismic hazard issues in Hainaut. First,….]

Line 614 - " Our analysis provides new perspectives for seismic hazard assessment in Hainaut by three aspects. First, it demonstrates the importance of developing a GMPE for the Hainaut area that is more in line with the observed rapid intensity decay with distance than the current existing European GMPEs". Right, but if the rapid attenuation is dominated by the shallow depth of the local seismicity, improving existing GMPEs should not be so important. The authors should clarify this point.
R1 asked for a comparison between the Hainaut attenuation and other regions worldwide subjected to shallow seismicity. The fact that for similar depths and magnitudes the Hainaut attenuates faster, more appropriate GMPEs that are in line with the observed rapid intensity decay with distance should be applied. Moreover, the rapid attenuation is not only a function of the shallow depth but also of the mechanical characteristics of the fractured (and slow) coal basin. We clarified this point in the updated conclusions.