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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Spatial Seismic Hazard Variation and Adaptive Sampling of Portfolio Location Uncertainty in Probabilistic Seismic Risk Analysis" *by* Christoph Scheingraber and Martin Käser

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Thank you for this review and for sharing your view of PSHA. Please find our answer to each of your comments below.

Comment:

» [. . .] I therefore recommend that all such mss, including the present ms by Scheingraber and Käser, should be rejected, unless and until they can refute the criticisms of Mulargia et al (2017). The above recommendation may seem harsh to these authors,

as innumerable papers on PSHA or based on PSHA continue to be routinely published. But unless at some point papers on PSHA start to be rejected, they will go on being published forever.

Answer:

This comment does not refer to the actual content of our paper, but to the method of PSHA in general. The referenced critique is concerned about the theoretical or physical "validity of PSHA", but we are more interested in the practical benefits the method provides to society.

PSHA – since its first publication by Cornell in 1968 – has been improved in many aspects, especially with regard to its inherent uncertainties. Its benefits are broadly recognized by scientists and practitioners working in PSHA and related fields such as seismic risk analysis and seismic engineering. No better approach has been proposed, which is probably why PSHA continues to be used. To quote the famous statistician George Box: "All models are wrong, but some are useful".

Having co-authored all of the cited papers, the reviewer Robert Geller is a vehement critic of PSHA. The paper co-authored with Kagan and Jackson from 2012 – and cited to support this critique of PSHA – does in fact not even mention PSHA. It criticizes theories in seismology like "earthquake cycle", "seismic gap", and "characteristic earthquake". We agree on most statements of this opinion paper, but do not see any direct or tangible criticism of the general framework of modern event-based PSHA.

Concerning the two other cited papers (from 2012 and 2017, also co-authored by this reviewer), we again agree with their main points that PSHA cannot provide an accurate measure of hazard, and that it must not be used with blind trust (Quote: "Geoscience consultants feed information into the PSHA machine, the crank is turned, and a seemingly objective number pops out."). Since we developed our "PSHA machine" ourselves, we are well aware of its weaknesses and dependence on assumptions that sometimes are barely supported by reliable data collected over time scales long enough for cer-

tain seismological needs. One should keep in mind PSHA has its justification exactly in that it can be used to analyze the influence of purely constraint assumptions and quantify the ranges of possible hazard results. The output of PSHA is inherently based on probabilities and therefore it is always possible to find individual examples – as in the suggested papers – that do not nicely fit the model. In any case, abandoning the method entirely and relying only on qualitative judgement does not seem to be a wise recommendation; it is neither practical nor legally viable, because e.g. engineering and financial decisions and regulations require quantitative input.

However, we agree to the argument that the flaws and limits of PSHA and the uncertainties of its results have to be communicated effectively in order to provide a holistic view of risk and avoid "blind trust" in PSHA outputs. This is precisely why our work is concerned with the computationally efficient treatment of uncertainties in PSHA and PSRA, allowing to analyze the impact of poorly constraint or unknown parameters on risk assessment and to come to an informed decision. In this paper in particular, we analyze one of these aspects of uncertainty related to seismic risk assessment: insured portfolios often have poor geospatial data quality. We show how the huge uncertainty space can be investigated efficiently by using variance reduction methods, i.e. adaptive sampling strategies instead of simple Monte Carlo simulation. PSHA is just used to get an input parameter for the sampling method we propose for seismic risk analysis, and our method can help to validate PSHA and PSRA more effectively.

We are therefore a bit surprised that Robert Geller did not recognize that our work is actually in line with most of his argument. We assume that our holistic view of PSHA and PSRA was not made clear enough in the abstract and early sections of our original manuscript. To improve this, in our updated manuscript we have added some clear statements about the weaknesses and limits of PSHA and PSRA:

- Page 1, Abstract, Lines 2-4: "The available seismological data is often limited, resulting in many uncertainties and assumptions. The situation is further aggravated by the sometimes poor data quality with regard to insured portfolios."

- Page 1, Abstract, Lines 16-17: "The results show that the scheme can improve the efficiency of the estimation of loss frequency curves, and may thereby help to spread the treatment and communication of uncertainty in Probabilistic Seismic Risk Analysis."

- Page 1, Section 1 Introduction, Lines 19-20: "Seismic risk analysis is widely used in academia and industry to model the possible consequences of future earthquake events, but is often associated with poor data quality, resulting in the necessity for many assumptions and a wide range of deep uncertainties (Goda and Ren, 2010). The treatment and communication of uncertainties is highly important for informed decision making and a holistic view of risk (Tesfamariam et al., 2010; Cox, 2012; Bier and Lin, 2013)."

- Page 2, Section 2.1 Probabilistic Seismic Hazard and Risk Analysis, Lines 27-28: "PSRA is based on Probabilistic Seismic Hazard Analysis (PSHA; Cornell, 1968; Senior Seismic Hazard Committee, 1997), which relies on a number of assumptions outlined in the following."

- Page 23, Section 6 Conclusions, Lines 2-4: "Seismic risk assessment is associated with a large range of deep uncertainties. For example, the exact location of risks is often unknown due to geocoding issues of address information. In order to provide a holistic view of risk and to be able to communicate the effect of uncertainty effectively to decision makers, all model uncertainties need to be treated. Therefore, in this paper we propose [. . .]"

- Page 25, Section 6 Conclusions, Lines 14-15: "The effect of modeling assumptions and the often poor data quality needs to be investigated further."

Comment:

» 1) This referee's impression is that PSHA gives ever more unreliable results as the grid is made finer and finer. Notwithstanding the inherent flaws in PSHA, if the regions were made larger and larger the central limit theorem would probably mean the results

were more safely usable. Maybe this is like the tradeoff between stability and resolution in inverse theory.

Answer:

Unfortunately, it is unclear to us to which “grid“ this comment refers to. In our paper we are mainly referring to “grid“ in the sense of a weighted irregular grid that represents potential locations of insured assets. This concept is explained in our paper and is necessary to spatially distribute insured values given only on administrative geographical zones. This grid is not related to the spatial accuracy of analyzing the seismic ground motion or seismic hazard output. It is also not related to another grid which is typically used to model potential earthquake epicenters within an area source using the method of gridded seismicity. Therefore, we believe this comment comes from a misunderstanding of the term “grid” as it is used in the context of this paper.

Comment:

» 2) The quality of the writing is generally good, but there is one typo on page 25. The family name of the first author is “Petersen” not “Mark Petersen.” Ditto for the other coauthors. And in the body of the text this paper needs to be called out as “Petersen et al.,” not “Mark Petersen et al.”

Answer:

Thanks for pointing this out, we have corrected the typo in the citation of Petersen et al. (2007).

Comment:

» Both authors list “Munich Re” as an affiliation on the title page, and the acknowledgements list “Munich Re” as a sponsor. Thus (see line 20 on page 22) the declaration of “no competing interests” is incorrect and must be rewritten. Munich Re sells consulting services and insurance products based on PSRA, and this fact must be appropriately stated in the “competing interests” declaration. [. . .]

Answer:

We think that this comment is misleading, as one might conclude that Munich Re potentially profits in any material sense from having provided financial support for this academic research. There was no business-related influence on this paper and there is no financial interest of Munich Re in publishing scientific papers. In fact, Munich Re is highly interested in making academia aware of some of the crucial problems arising in Probabilistic Seismic Risk Assessment (PSRA), as well as in trying to solve them in a way of best scientific practice.

While working on this project, the first author has not been affiliated with Munich Re, but has been a PhD student at Ludwig Maximilian University of Munich and funded by Munich Re. It is the right and duty of a PhD-student to publish scientific results and discuss the applied approaches and findings with the scientific community. Since the first author has not been affiliated with Munich Re while working on this project, we have removed this affiliation and apologize for the confusion this might have caused. To clarify this and the role of Munich Re in this research, we adjusted the “competing interests” declaration accordingly.

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