Review of "Integrating faults and past earthquakes into a probabilistic seismic hazard model for peninsular Italy" by Alessandro Valentini, Francesco Visini and Bruno Pace
Manuscript NHESS-2017-41

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General Comments

The manuscript provides a procedure to integrate active faults in a regional seismogenic source model for Italy. A database of active faults was compiled and fully parameterised for use together with observed seismicity (instrumental and historical) to forecast the spatial and temporal distribution of future seismicity. Earthquake recurrence models of the delineated active faults are model by two magnitude-frequency distributions: either a Characteristic Gaussian (CHG) or Truncated Gutenberg-Richter (TGR). Additionally, the seismicity off faults is described by a smoothed seismicity using a complete earthquake catalogue of the region. The two models are complementary not independent, thus the earthquake rates account for double-counting of earthquakes assigned to faults above specified threshold magnitude. Further, a novel weighting function to correct the earthquake rates in vicinity of fault sources is proposed and used. The resulting two seismic sources are eventually combined in a mixed source model representing the suitable activity rates in time and space. The authors conclude with a sensitivity analysis evaluating the impact of the two models of earthquake recurrence rates on the total seismic hazard.

The use of active faults in seismic hazard assessment has become extensive in the last decades due to efforts of data compilation and analysis. Active faults provides the information to extend the observational time of large magnitude earthquakes which often is not captured by the existing catalogues of observed seismicity. The current manuscript provides a step forward into this direction. The combination active faults and smoothed seismicity is not a novel procedure but rather state of practice. Overall, the manuscript is relatively well written, there are several misleading parts to be improved, highlighted in my detailed comments. The structure of the manuscript is consistent with the procedural steps and no major changes are required. The figures, tables and supplemental materials are clear and appropriated. There are some key references missing but this is not necessarily a criticism. The conclusions appear appropriate with the proposed procedure and analysed content. My comments follow the structure of the manuscript and summarised below:

1. First and foremost the authors should be clearly state that this is not an update of the seismic hazard model of Italy, and that the purpose of the study is to integrate the active faults in a hazard calculation. Moreover, the resulting seismogenic model presented in this study has limitations, such as the use only of shallow faults, but not the subduction and volcanic sources.

2. A definition of active fault in the context of the study must be introduced. The literature distinguishes between active faults in geological time, i.e. Quaternary or Neocene, capable of future reactivation. Moreover, the slip rate assumptions must be discussed. It is well accepted that large variability are associated with the slip-rate values, and some portion of slip-rate can be aseismic. Extension of this discussion must be introduced in the context of this study.

3. Further, the authors are aware of the 2013 European Seismic Hazard Model (ESHM13, Woesner et al 2015) developed within the SHARE Project. It might be worth discussing the two approaches side by side, as the ESHM13 is the first reference model to introduce active faults for Euro-Mediterranean Region.

4. There are several procedural steps that are not well explained in the document, such as the estimation of the activity rates for faults. Albeit, the main focus of the procedure is to implement active faults to seismic hazard, the activity rates are yet described as input to the FiSH code and the segment seismic moment conservation. In my opinion this is not enough. The key elements and assumptions for computing the activity rates of active faults needs more attention, supported with discussions of the sensitivity of the input parameters, i.e. the effect of slip rates to earthquake recurrence rates.

5. The role of each magnitude frequency distribution (MFD) for each fault is not clear as described in the current version. One might expect a logic tree of the two MFDs. This aspect needs to be emphasised in the introduction.

6. Maximum magnitude assigned to each fault based on empirical magnitude scaling relationships do not account for uncertainties of the fault size (subsurface length or area). From the current version of the manuscript it is not evident the error associated to the fault size in the fault dataset.

7. Also, one can argue that more recent magnitude scaling relationships can be used (e.g Leonardo et al 2010) but for those used, the role of aleatory uncertainty must be mentioned and quantified herein. The authors should describe the procedure implemented in the FiSH code because not everyone has access to that manuscript.

8. Five maximum magnitude values are described as being assigned to each fault. The way these five values are implemented in the final computational model is not clear. Are these values modelled in a logic tree?

9. A sensitivity analysis to the choice of the maximum magnitude may be necessary to explain the effect of maximum magnitude for the TRT. For the same slip rate increase of the maximum magnitude will result in a decrease of the recurrence of small events. This effect is due to the fact that the largest earthquake accounts for most of the seismic moment and this requires the subtraction of small events to maintain the seismic moment balance.

10. In a general way, the characteristic model implies a recurrence rate estimated on large past large-magnitude earthquakes recognised from past geological record and the time interval between events can be measured. How many of the faults have a geological record long enough to characterise the recurrence of the large magnitude events? In the current version of the manuscript the historical events are linked to the faults, thus the long-term representation of the fault activity is questionable.

11. Slip rates are averaged over successive geologically recognised earthquakes and prone to error in measurements, hence the uncertainties of the slip-rates needs to be quantified.

12. When combining active faults and background seismicity, it is mandatory a comparison of the seismic productivity (CHG and TRT) of the faults with the gridded seismicity in the vicinity of faults. Without such comparison it is difficult to assess the performance of the models.

13. Generally, evaluating the performance of seismogenic sources based on seismic hazard estimates is not recommended. The hazard estimates based on active faults only is misleading, as the active faults are incomplete in space, and not treated as independent models. Thus the model performance may be evaluated at the level of seismicity rates comparison, not for hazard estimates.

14. The authors should state clearly that a suitable seismogenic source model combines the active faults and the gridded seismicity as mixed model.

Section Specific Comments

L50:51: “In Europe, a working group…“ In Europe, within the SHARE project (Giardini et al 2010) has introduced the use of active faults at the region level for the first time. I am surprised that the authors do not refer in their study to the fault source models for Italy, the DISS (Database of Individual Seismogenic Sources). What are the main similarities and differences between the two dataset? The authors may consider adding a reference and a discuss the two datasets to avoid confusion.

L63: 66 The uniform seismotectonic sources of the Italian hazard described by Stuchi et al (2011) are delineated considering the fault information where and when available. The more realistic pattern of ground motion due to faults it is questionable, because an area source delineated to describe a group of faults, it will produce a similar pattern with the individual faults. The major benefits of using the active faults is to extend the observational time to capture the recurrence of large magnitude events. The local pattern due to fault location might be controlled by other factors such as hanging wall, upper seismogenic depth, style of faulting. However, these effects are not evident if an inappropriate ground motion model is selected. Thus the seismic hazard pattern depends on both seismic source representation and ground motion models.

L72. The term models is misleading. A source model implies a complete source representation in space and time aimed at describing the seismogenic potential of the region. In the current context, the active faults are incomplete in space, they are not describing all the tectonics of the region - not volcanic, subduction or deep seismicity reported for the Italian territory. It has to be specified that these are individual seismic sources, but not independent models. The procedure proposed here is aiming at creating a “model” for an exercise of seismic hazard evaluation. Moreover, if the goal of the work is to provide a robust seismic hazard estimates, then the authors resolve the issues of model independence and completeness as well as to capture the epistemic uncertainties in the mixed source model.

L120: The time scale is a key aspect to evaluate the long-term representation of the seismic productivity of active faults. If a fault has moved in the recent geologically time , i.e Holocene, it might be considered as seismically active, if it moved in the far-off geologic time and has not moved again since then the fault might be judged to be an inactive fault. Hence, it might be of interest to specify the time scale and the definition of active faults on the present investigation. Yet, as mentioned before there is need to clarify the definition of fault activity or non activity.

L131:135. The sleep rate values for some faults are very low. Values of 0.3 mm/year are extremely low and the movement on these faults could also takes place as creep. Is the aseismic factor adjusting the slip rates? Are these slip-rates supported by historical seismicity observations, geological investigations and /or paleoseismicity studies?

L152: The name could be “Segmentation rules for delineating (or aggregating) fault sources”

L199: The role of aspect ratio must be discussed in greater extend than currently version. The extension along-strike dimensions of the faults seems to be constrained by this parameter.

L191: There are five Mmax values for each fault. How is the Mmax modelled in the hazard calculation?

L202: Introduce and explain the “segment seismic moment conservation”? The key assumptions and the input parameters of the recurrence rates must be described. Characterisation of the active faults is a key aspect of this approach, thus it requires more description. As mentioned before, the effect of maximum magnitude must be discussed. In the case of seismic moment balance, for a constant slip rate, the recurrence rates of small events are decreasing with increased magnitude.

L207:211: What is the rationale of the two MFDs? It is not evident why the two recurrence models are selected? In a general way, the characteristic earthquake is used to define an earthquake of a given magnitude and well identified recurrence time by geological evidences. The fault sources used here do not qualify for such model, for various reasons including the way they are constructed by linkage of various segments. A characteristic model will be appropriate for use on individual segment rather than a long composite fault. See discussions of Kagan (1993), that clearly states that the evidence of the characteristic earthquake hypothesis can be explained either by statistical bias or statistical artifact. Thus, it will be of great interest for the readers to specify the assumptions for the two MFDs.

L278: the number of Voronoi polygons is not clear to me. There are 3 to 50 polygons across the entire region? Each polygon is tectonic dependent? Please clarify.

L286: Who is parametrised the depth and the maximum magnitude for gridded seismicity? Are these parameters treated as aleatory or epistemic?

L382: For the purpose of an exercise one GMPE might have been justified. However, the focus of the study should be the comparison of the earthquake recurrence rates not the hazard estimates.

Recommendation: Accept for publication with major revision