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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "When probabilistic seismic hazard climbs volcanoes: the Mt Etna case, Italy. Part I: model components for sources parametrization" *by* Raffaele Azzaro et al.

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Dear Celine, thank you very much for the careful revision, we appreciated your comments and suggestions aimed at improving the manuscript by clarifying not fully explained passages. We answered to all the questions you raised and modified the text accordingly. Hereinafter the detailed list of your comments and our replies, a zip file containing the revised manuscript with tracked changes, and the new figures that have been modified. On behalf of all the authors Raffaele Azzaro

R2. Main remarks With a title announcing a PSHA framework, the reader expects a description of the final model used for probabilistic calculations. However, the authors do

not explain how the different recurrence models will be combined to build final models, and how the source model logic tree will be built. Will the area zones and fault models constitute alternative models ? Is the gridded seismicity used as background for the fault model, and how? This information is essential to understand how the source model for PSHA is built.

We agree with you, this is a point raised by the other reviewer too. We decided to accept some overlapping with Part II paper for having a more readable and stand-alone paper. We thus entered some new lines in the introduction and a new block of text now marked as Chapter 6, where we added a picture representing the logic tree approach (taken from Part II paper).

R2. Section 3 Section 3, addressing earthquake recurrence from historical data, is a quick summary of a published paper (Azzaro et al. BGTA 2012). An interesting work has been done to estimate probabilities of occurrence of earthquakes on faults. However, as it is, it is not possible to fully understand the text and the results (inset figure in Fig. 2). Either this part has to be expanded, or it should be reduced and refer more strongly to the 2012 paper. Why the 1st case "events occurring everywhere inside the SZ Timpe" leads to "eight intertimes", and the second case "events occurring at the scale of individual faults" leads to "six intertimes"?

Yes, we agree. So we removed the text referring to the 1st case (events occurring everywhere inside SZ Timpe) since these data are not used in the work or in Part II paper, and maintained only the results regarding the 2nd case (events occurring at scale on individual faults). However, the readers can find further details in Azzaro et al. BGTA 2012 cited in the text.

The inset of Fig. 2, probabilities of occurrence of an earthquake in the next 5 years, refers to the 2nd case (+ why considering a 5 years period?)?

The 5 years period was chosen as representative of short-term earthquake rupture forecast in a high seismic rate region like Etna.

Apparently, faults are assumed to have the same mean recurrence time, but this is not explained.

Now it is clearly specified.

The inset is too small to correctly appreciate the curves.

We fixed this problem by enlarging the inset figure.

The time-dependent model, Brownian Passage Time model, should be introduced.

The text has been now modified and introduced the relevant reference.

The last sentence, referring to a bootstrap analysis, is difficult to understand without more explanations on the test done.

The sentence has been put forward to link it better with the intertimes analysis.

R2. Section 4 Section 4 describes the instrumental earthquake catalog, the delineation of area sources, the determination of seismogenic depths, the estimation of Gutenberg-Richter models for the area source zones, and the estimation of recurrence parameters for a gridded seismicity model. Area sources here are buffer zones around faults. Can you give more precisions on how this buffer zone is delineated (width, association of earthquakes with the fault)?

The text has been slightly modified.

Frequency-magnitude distributions based on the instrumental data is compared to the frequency distribution based on historical data. Why not combining both? E.g. at the scale of the Timpe zone, combining both would lead to a recurrence model fitting both the instrumental magnitudes (interval 2-3.5) and the historical magnitude rates (interval 3.5-5.0), instead of over-estimating slightly the historical rates? Magnitudes larger than 3.5 are contributing strongly in the probabilistic hazard estimation.

The basic assumption we accept in our analysis is the representativeness of few years

of high quality seismic monitoring during an interseismic period for the long-term seismic rates of faults: this assumption on annual/multi-decadal timescale recurrences is, in our opinion, supported by the global agreement of short term occurrences (red dots in Fig. 6), with the ones obtained with the whole catalogue (blue dots). Note that all the rates in Fig. 6 are annual rates, and we added the length of the historical catalogue so that the readers can estimate the completeness of low/high magnitude (we believe the departure of blue dots from the G-R at M∼<3.5 are due to incompleteness); consider that usually this kind of graphs show rates that cannot be linked at all. The inner coherence in treatment suggested us to avoid the simultaneous fitting of both instrumental and historical rates (what to do for Pernicana, for example?).

Nothing is said about the presence of clustered events in the catalog (swarms, foreshocks, aftershocks?). How do the authors handle this issue, which is of importance when establishing earthquake recurrence models and calculating b values?

The extrapolation of a short interseismic period is the key for avoiding declustering in the catalog. Consider that our final aim is modelling a generalized non-Poisson process, as this is more adequate to represent the seismicity in volcanic areas. In terms of seismic moment and number of events, note the regular trend of the cumulative curves in Fig. 3. We modified the figure and slightly the text.

R2. Distributed seismicity Rather than arbitrarily excluding cells where “strange” b-values have been obtained, would it be possible to apply some criteria on the estimation of the b-value, e.g. increase the minimum number of events in the cell or impose a minimum magnitude range available? These criteria would ensure the reliability of the recurrence curve inside each cell. Besides, are the b-values obtained within the values expected for volcanic areas? It is hardy possible to locate the b-values mapped in Fig. 8, without any topography or country border.

Your comment is great, we performed several tests by changing the search radius, minimum number of events, minimum magnitude, and fitting algorithms too. The final choice here presented is a compromise to have a formal procedure (outliers removal) for selecting automatic results. We added some words on that, and put geographic references on Fig. 8. About the b-values of volcanic areas, as answered to the other referee, we observe the highest ones in the central craters; completeness and detection capability of the network will surely affect the corner toward the sea.

R2. Section 5 The magnitude-size scaling relationship for the Taupo volcanic zone is compared to the relationship for Mt Etna, then both are used for estimating maximum magnitudes. Is it correct to compare 2 relationships established on disjoint datasets (for Taupo, minimum length is larger than 10km, while for Etna maximum length is around 10km) ? Could you add a short discussion on extrapolating scaling relationships?

We used both MSRs for minimizing the epistemic uncertainty associated with them. In any case, the effective interval of extrapolation is narrow, since the length of faults to be used for estimating maximum magnitudes is mostly in the range 7-11 km, i.e. next to the lower part of Taupo MSR (see Fig. 10, frame b, length in logarithm scale). We now added a comment on this aspect.

The section concludes saying that "the mean recurrence times associated to Mmax values vary from 22 to 166 years, periods generally consistent with those historically observed for the individual faults". I don't understand the sentence, as the mean recurrence time estimated from the historical dataset is 71 years (Table 2).

The referee comment is correct. We rephrased the sentence.

How is the aperiodicity factor estimated in this model (Table 2)?

The aperiodicity factor ïĄą, defined as the standard deviation of the recurrence times over their mean, has been estimated by introducing formal error propagation to take into account the uncertainties in Mmax and slip-rates and so to explore how these uncertainties affect the variability in Tmean (details in Peruzza et al., 2010 and Pace et al., 2016).

R2. Other remarks Section 3.1 should be suppressed, as there is no Section 3.2. We put the paragraph (3.1) since we wanted to highlight the topic of the characteristic magnitude and related recurrence time, separating it from the general overview on the historical seismicity.

Section 4, Figure 6: the time period used to estimate annual rates of historical earthquakes for SZ Timpe, FF, STF-SVF, MF-SLF, should be the same? As the completeness of historical data must be homogeneous within the rather small Timpe zone? The time period indicated in the legend, 1832-2015, corresponds to a larger time window, 184 years. Why reducing this time window to 138 or 142 years to calculate annual rates? Please make this point clear, as it is confusing.

Your comment is right, the annual rates for the Timpe area of historical earthquake data are equally setto the large time window 1832-2015, the different years shown in the figure refer to the Tlast-Tfirst event inside each area. For Pernicana fault (PF), we cannot state the same completeness period, as it was a deserted area till late 1970s, and therefore local macroseismic effects are not documented. Again the years indicated (35) refer to the interval between the first and the last event assigned to that area, in the historical earthquake catalogue. We did some effort for better explaining it.

L 248: "This overall picture is consistent with the inter-time distribution of earthquakes (Sicali et a; 2014)" : please, how do you relate b-values with inter-time distributions?

We did not enter into much details with respect to results of the inter-event time (IET) distribution analysis as they can be found in the paper by Sicali et al. (2014). In the text we referred to analogies in the patterns, at different seismogenic depths, of b-values and IET distributions, fixing their seismotectonic significance. The text has been now modified to make clearer this.

Table 2: should be cited in Section 3 dealing with mean recurrence times.

We cited it in Section 3, by renumbering the tables and inverting the columns, as many data are not comprehensible at this stage we added a disclaimer phrase.

Why providing the “Mmin for which is calculated the probability of occurrence” as it is not mentioned nor discussed in the text?

This is an oversight; Mmin is referred only to the minimum magnitude of the instrumental dataset, and not to the probability of occurrence. We corrected the text in the caption.

L184-185: “This option has a dual purpose: i) to provide a less detailed characterization mediating features inside heterogeneous, “ => there must be a word missing?

Yes, the sentence has been rewritten. L 295: “Considering the approximations due to the use of different dimensional measurements, the comparison is fairly explanatory” => exploratory?

The term “explanatory” is correct.

L 321: See tab 1 : should be Table 2?

Yes, we corrected this citation.

R2. Conclusion L350: “Taken as a whole, the FMD of the SZ Timpe is similar to the FMDs and depth distributions of the Moscarello (MF) and S. Leonardo faults (SLF), whilst the Fiandaca Fault (FF), S. Tecla and S; Venerina faults (SVF) show, respectively lower and higher b-values and activity rates.” => sentence which is confusing and needs to be re-phrased. MF and SLF belong to the same SZ. Timpe encloses MF-SLF, FF, and STF-SVF, so the seismic rates in Timpe must be higher or equal to the sum of these 3 FMDs.

The sentence is a just comment on the general features of the whole SZ Timpe compared to the individual area sources. However, the difference you observed can be accounted for: i) the SZ Timpe also includes two small triangular areas (see upper right panel in Fig. 6), adding other 183 earthquakes (see also Fig. 4 caption that

reports the number of eqs for each SZ and the whole SZ Timpe); ii) the weight of eqs of MF-SLF in terms of seismic moment released is much higher compared to the ones of FF and STF-SVF, and hence the similarity between SZ Timpe- MF-SLF is more evident. We modified the text accordingly.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-127/nhess-2017-127-AC1-supplement.zip

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