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Comment on nhess-2022-46

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Referee comment on "Quantifying the probability and uncertainty of multiple-structure rupture and recurrence intervals in Taiwan" by Chieh-Chen Chang et al., Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2022-46-RC2>, 2022

Chang et al.'s manuscript address an interesting and relevant problem: three decades after the observation that two separate faults can interact in such ways that the rupture of one may trigger the rupture of the other (Stein et al., 1992), how can we incorporate this phenomenon in hazard assessment? The authors use a database of seismogenic faults in Taiwan to investigate the likelihood that such stress triggering of earthquakes could take place over a given period of time, and to quantify its impact on seismic hazard.

The authors apply an analytical procedure inspired in Chan et al. (2020), which stems from the notion that when two faults interact each one gives part of its slip rate to the multiple-rupture process, while retaining the remaining slip rate to its individual-rupture process. Starting from this basic notion – the "partitioned slip rates" of Chan et al. (2020) – the authors use Kanamori's (1977) definition of moment magnitude, the definition of seismic moment, Wells and Coppersmith's (1994) scaling relations of moment magnitude with rupture area and the Gutenberg-Richter relation to obtain return periods for multiple ruptures and for individual ruptures on each fault.

Key to the authors' reasoning is their assumption that the slip rate of each fault is partitioned between individual and multiple ruptures according to a "partitioned rate" given by their equations 10 and 11, which include "the magnitude of the multiple-structure rupture" (line 135) and "the displacement of the multiple-rupture structure" (line 136). This terminology reflects the fact (not explained in the manuscript) that the catalog used in the study considers characteristic ruptures only. The expression for C features the b -value of the Gutenberg-Richter relation. The authors present the expression for C as a logical conclusion of the Gutenberg-Richter relation, although I was not able to follow that logic. I was able to trace the definition of the partitioned rate C to Chan et al. (2020), but there too it was introduced without an explanation.

The authors estimate a return period for a multiple rupture in a pair of faults as $R_{12}=D_{12}/D_{12}'$, where D_{12} is a displacement associated with the joint rupture of the two

faults and D_{12}' is a slip rate associated with the joint rupture of the two faults. To obtain D_{12} the authors use the definition of seismic moment inserting for A the sum of the two fault areas and estimating the seismic moment from a value of magnitude inferred from A using the Wells and Coppersmith (1994) scaling relations. To obtain the multiple-rupture slip-rate the authors assume that $D_{12}' = D_1^{12}' + D_2^{12}'$, where D_k^{12}' is the part of the slip rate of fault k that takes place through joint rupture (estimated with the partitioned rates discussed above). It is important to inquire into the physical meaning of these quantities. The estimate of the multiple-rupture displacement is formally correct, albeit highly convoluted. But the estimate of the multiple-rupture slip rate through a sum defies logic, in my view (why sum slip rates interesting separate faults?) Also, as pointed out above, each parcel relies on a coefficient that was not sufficiently explained.

In section 3.2 the authors enlarge their approach to include more than two faults in interaction, increasing the complexity while inheriting the obscurity from the previous section.

In sections 3.3 and 4, the authors discuss some implications of their analysis for seismic hazard. Around line 245, the authors conclude that the possibility of multiple-rupture earthquakes reduces the hazard at the shorter return periods while increasing it at longer return periods. In line 255, the authors observe that "structures that pair with several cases of multiple-structure ruptures might be difficult to rupture solely". These observations are so clearly at odds with empirical evidence – which points to single-fault rupture as the dominant contributor to hazard – that they should be regarded as indicating flaws of the approach.

The authors base their approach on a simplified view of stress transfer between faults: they ignore dynamic effects, pore-fluid effects and – surprisingly in view of published evidence – restrict the range of stress transfer to 5km. Although the title promised a quantification of the uncertainties, very little is done to quantify the errors that derive from such simplifications. In line 263 the authors state that their approach is a physics-based one. Unfortunately, it seems to have strayed strongly from the geological reality of earthquake generation. The authors recognize, to their credit, that the "analysis could be further improved through better understanding seismogenic structures" (line 278). I would take this conclusion even further and say that the analysis needs to be reformulated starting with a better understanding of seismogenic processes. For example, exploring empirical evidence of the occurrence and characteristics of multiple-rupture earthquakes in the available databases, in order to be able to subject their model to a reality check.

In the present stage of development, I regret to conclude that I don't consider this research ready for publication.

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