

## ***Interactive comment on “Hazard Interactions and Interaction Networks (Cascades) within Multi-Hazard Methodologies” by J. C. Gill and B. D. Malamud***

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Gill and Malamud discuss a general framework for extending the commonly taken view on hazard assessment by taking interdependences of different types linking various hazards into account. Since such interdependences may significantly affect the susceptibility of regions to hazards of different types, I fully agree with their basic argument that hazard interactions need to be carefully considered for obtaining qualitative and quantitative risk assessments. The discussion presented by the authors is scientifically sound and does not only highlight the insufficiencies of previous approaches, but also proposes possible ways to reaching such realistic assessment. The latter aspect appears to be the main achievement of the present work that goes beyond what has

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been discussed by the authors in their recent review paper (Gill and Malamud, 2014). At the present stage, this work is purely qualitative, and future studies describing its further extension towards quantitative multi-hazard risk assessments would be most welcome. To this end, this excellent work can be considered as an important milestone on this way.

While the manuscript already presents excellent work, I would like to recommend additionally paying specific attention to some minor points listed below to possibly make it even better:

1. Regarding the anthropogenic processes briefly discussed in Section 3.2, I think that another possibly important example of such processes would be induced seismicity, i.e., seismic activity resulting from human activities like construction of large artificial reservoirs or mining/drilling activities. Recent corresponding references on possible cases of induced seismicity include, among others, Kerr and Stone, *Science* 323, 322, 2009, or Hough and Page, *Bulletin of the Seismological Society of America*, doi: 10.1785/0120150109. I would like to suggest adding some brief comment on such anthropogenic processes.

2. In Section 3.3, the authors state that "similarities exist between the routine hazard events of technology and the definition of anthropogenic processes". Frankly speaking, I do not clearly understand the exact differentiation between both types of hazards from the present discussion. Providing some explicit examples highlighting this difference could be helpful to clarify this point.

3. Regarding their discussion of interaction relationships, I have got the impression that the authors consider such relationships as exclusively unidirectional. Or put differently: the present framework is developed and illustrated with the (in my opinion, unnecessary) implicit restriction of unambiguous cause-effect relationships among hazards (as manifested in the terminology of primary versus secondary hazards). In this regard, I was wondering if there exist any examples of bidirectional interactions, either associ-

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ated with their simultaneous occurrence or relating to feedbacks. I would be keen to learn about the authors' opinion on this question.

4. In Section 4.1, the authors describe triggering relationships as "causal" relationships (as opposed to the other two types of interactions among hazards). However, depending on which specific notion of causality is considered, I would argue that the other two types also denote some "causal" (in the sense of directional) relations, yet of different quality than triggering relationships where this relation is "most direct".

5. The authors emphasize (p.7, l.28) that triggering interactions can occur between a diverse range of hazards and processes. I think that also the issue of scales (both temporal and spatial) is something important to consider when aiming to characterize triggering relationships. It might be interesting to elaborate further on this aspect.

6. Throughout Section 4, there is considerable redundancy between figure captions and the main text (e.g., between the last paragraph of Section 4.1 and the caption of Figure 2). I think that this redundancy should be reduced.

7. In Section 4.2, the authors state that increased probability relationships "change the frequency or extent of the secondary hazard or process". When considering hazards in some abstract (probabilistic / return period) sense, I agree with this. However, at the level of individual events, a specific primary event would rather change the proximity (and specific characteristics) of the specific next secondary hazard to come affected by the increased probability relationship. From the present paper, it is not always completely clear if the authors wish to consistently take the probabilistic or the individual event viewpoint (not necessarily contradicting each other in general).

8. In Section 4.3, the authors contrast interaction relationships that "include large numbers of frequently-occurring interactions" and such "that are considered to be less common". This seems to me a rather arbitrary distinction (i.e., there are no two distinct types, but rather a continuum of cases according to the frequency of interactions). I was wondering if the authors have any objective criteria for associating catalysing and

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impedence relationships to any of the two aforementioned types.

9. In Section 5, the authors first refer to four case studies, later to two. The first two cases detailed in Section 5.1 are not used any further in the following text, while the other two cases are exclusively discussed in the visualization context. All four examples are clearly relevant in the context of this work, but the way they are introduced and detailed in different parts of the manuscript appears slightly confusing.

Despite not being a native speaker, I was wondering about a few words and kindly ask the authors to cross-check them:

\* p.3, l.26: "selected"

\* p.9, l.21: "...processes relevant interactions can be..."

\* p.10, l.15: "evaluating networks... is important"

\* p.15, l.27: The meaning of the term "Earth-systems management" is not fully obvious to me.

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