

# ***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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The paper discusses the importance of modeling the interactions among different hazards, natural and not, to obtain a more realistic risk assessment. The paper is well written (maybe with some unnecessary repetitions), and the topic of great interest. My general opinion is positive but I think that the paper misses to take into account some key issues for a proper multi-hazard assessment.

The first issue, and probably the most important, is that the authors do not discuss the forecasting time windows for hazard assessment. The importance of this topic for multi-hazard and multi-risk assessment has been already discussed in Marzocchi et al (2012; W. Marzocchi, A. Garcia-Aristizabal, P. Gasparini, M.L. Mastellone, A. Di

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Ruocco, 2012. Basic principles of multi-risk assessment: a case study in Italy. *Natural Hazards*, 62, 551-573), and it will be summarized here. The ‘hazard’ is essentially the probability of a threatening event in one specific time-space window. The (forecasting) time window is of critical importance and it is usually related to the specific use of the hazard assessment in terms of risk reduction. For instance, a long-term hazard assessment (e.g., a forecasting time window of 50 years) is usually adopted for land use planning, like to define the building code for the earthquakes threat. On the other hand, the management of rapidly evolving emergencies usually requires short-term assessments (e.g., days to weeks). Considering long- or short-term hazard provides completely different scenarios for hazard interactions. For example, let us consider the landslide hazard. We can calculate the probabilities of landslides occurrence for the next decades just simply looking at the historical catalog. The fact that most of landslides are caused by earthquakes is not relevant in the long-term hazard because this is true also for the landslides occurred in the past and reported in the historical catalog (assuming that the long-term earthquake rate is not changing with time). So, the interaction between earthquakes and landslides could be irrelevant for the long-term hazard assessment. Of course, if we are considering the short-term hazard assessment (as I guess the authors are doing), the fact that a large earthquake (like the Gorkha event) has just occurred modifies significantly the probability of landslides in the next few months (due to the occurrence of aftershocks). So, the interaction between hazards has to be considered specifying clearly the forecasting time window. Marzocchi et al (2012) explore in detail this point showing a probabilistic framework to explain when hazard interactions are relevant or not. (see section 3.2).

The second issue is that the authors seem to confuse the hazard with the risk. Hazard is an essential component of risk assessment, but it is not the risk. So, I think that introducing vulnerability interactions in the multi-hazard assessment is not proper (like they did in their figure 1). Again, Marzocchi et al (2012) addressed this distinction in their Figure 2. I emphasize that this distinction is not only semantic. In a multi-hazard/risk perspective, it is important to mention that hazards cannot be (usually) compared,

while the risks can. In fact, hazards are usually represented by curves that represent the exceedance probability of some quantity of interest, like ash fall thickness, ground shaking acceleration, etc. So it is not clear to me how we can compare them meaningfully and say when an hazard is higher than another one. On the other hand, the associated risks can be easily compared.

The final issue is about the distinction between “triggered” and “increase probability” made by the authors. This distinction is not clear to me. It seems that the authors assume that triggering is a deterministic link between hazards. In my view the concept of triggering and of increase probability are identical, at least this is true in seismic and volcanic hazard. We can talk of deterministic causal relationship only retrospectively (when you have already observed that one event triggered another one). But when we see the problem in a prospective way, the occurrence of an event *may* increase the probability to trigger another event, but very rarely we can be sure about this triggering. Of course the authors can mean something different, but I think that this distinction has to be clarified.

As a final suggestion, I would like to see a little bit more emphasis on the probabilistic and quantitative nature of hazard assessment. This is just a suggestion and it is not mandatory, but I do think that quantitative assessment of the hazard (and of the consequent risk) is the only possible strategy to plan rational risk reduction actions.

To sum, I am positive about this paper because it reiterates the importance of the interaction among different hazards in a multi-risk perspective. This is certainly commendable. However, I think that the authors should make an effort to address the points raised above.

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