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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "From Tsunami Risk Assessment to Disaster Risk Reduction. The case of Oman" *by* Ignacio Aguirre Ayerbe et al.

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RESPONSES TO REFEREE #2

First of all we really thank the Referee#2 for accepting the revision of the paper and for the opportunity offered to improve it through the valuable comments and suggestions proposed. We also appreciate a lot the technical revision and the corrections proposed. It is a great contribution for the improvement of the initial submission.

Below you will find your comments followed by our response. We have also attached a new version of the manuscript (Aguirre-Ayerbe_From TRA to DRR_Discussion_Manuscript_v2) with the changes proposed after your suggestions,

marked in blue. In addition, you will also find the changes anticipated following the suggestions of a second reviewer, which are highlighted in green. Lines referred in this author's response are the lines numbered in the version 2 of the manuscript attached to this response.

General Comments

The paper by Aguirre-Ayerbe et al. deals with tsunami risk assessment and strategies for risk reduction along the coast of Oman, presenting a comprehensive and integrated approach, that starts from the scientific aspect (hazard assessment), includes engineering methodologies (such as vulnerability indicators), and involves also the operative and human dimensions (involvement of stakeholders). Another important aspect is for sure the study and quantification of the human dimension of vulnerability, usually neglected or ignored in tsunami vulnerability and risk assessment. The approach adopted in this work, bridging different aspects and methodologies, is gaining importance in natural risk reduction perspective. In general, the manuscript is clear, well organized and well written (some remarks are reported below, in the "Technical Corrections" section). The results provide very interesting indications to the local authorities in terms of tsunami hazard and effectiveness of preparedness and preventions measures. The references are extensive and appropriate, such as no particular remarks are found concerning the pictures. The methodology section, on the contrary, needs some improvements (reported in "Specific Comments" section), probably leaving too much descriptions and details to other related works, where a similar approach or part of it was applied. The main weakness of the work is that no observations on tsunami hazard and vulnerability are reported, in order to understand if the proposed vulnerability indicators fit the local conditions (for example, building vulnerability classes are the same in Oman as the case considered in SCHEMA project?), and if the proposed countermeasures are really effective. In few words: it is possible to validate in some way all the assumptions taken for all the aspects (hazard, vulnerability and exposure, risk, countermeasures) considered. Apart from this aspect, the paper represents an

important step forward the integration between scientific and operational aspects, and is recommended for publication with minor revisions.

General response:

We thank the reviewer the analysis and reflections on this study. Major past tsunamis in Oman are not very detailed documented in terms of physical and human impacts, so no historical references are available to “calibrate” or “validate” the assessment . For the hazard assessment, one of the scenario considered is the historical event of 1945 (Heidarzadeh net al., 2008). For the vulnerability and exposure, present conditions have to be analysed (unless the objective would be to compare with past situations, which is not the case). For the building vulnerability function applied, it has been selected from SCHEMA study, based on similar building characteristics in Oman (these data come from post-tsunami observations collected by several authors in Indonesia in the aftermath of the 2004 Indian Ocean tsunami). Regarding the effectiveness of the measures, each measure included in the set of RRM proposed is based on previous studies (UNFCC, 1999; Nicholls et al., 2007; UNESCO, 2009a, Linham et al., 2010) and analysed and characterised by considering technical and economic requirements, possible supplementary measures, efficiency, durability and initial cost analysis. Besides, local (country) capacities to implement them is analysed based on the information provided by the ad-hoc (local) experts group panel. In addition, a SWOT analysis has been performed for each measure, in which experts and past experiences are considered. Each measure (developed on RRM-cards format, as pointed out in the paper) incorporates a bibliographic reference list.

In conclusion, local characteristics and other experiences have been considered as much as possible. This said, is important to clarify that the goal of this study is to provide a framework and some management tools to improve the preparedness of the country to a tsunami event. The tsunami risk assessment performed, together with the risk reduction measures identified are essential for the risk-management preparedness strategy. Thus, improving preparedness will improve the capacity of the country to face

a tsunami event.

Specific Comments

1. INTRODUCTION

REVIEWER COMMENT: Has this approach been applied to other cases? Which difficulties and could raise in other areas, and which changes should you perform on the vulnerability indicators?

RESPONSE: There are several studies and international DRR institutions applying indicators-based approaches to perform risk assessments to several hazards, some of them mentioned in current lines 54-60. These studies are very helpful to carry out an appropriate selection and definition of the indicators, at different temporal and spatial scales. Some of them have been validated considering past events (e.g. World Risk Index; González-Riancho et al., 2015; Papathoma-Khole, 2016). Following these works, some basic indicators (analytically and statistically sound) should not be ever neglected. If we consider an assessment with a similar scope and scale of work, local conditions should be considered as much as possible in the definition of the indicators, for the integration of context-specific problems. These local characteristics are usually related to very detailed information and limitations often appear regarding data availability and/or quality and confidence. This is one of the main constrains/limitations. Indicators in general must be appropriate in scope, understandable, easy to interpret and comparable. Some clarifications following these ideas have been included in lines 464-465.

2. METHODOLOGY REVIEWER COMMENT: Line 130. Maybe it is better to specify that COMCOT account also for land flooding using the moving boundary technique.

RESPONSE: We agree with this reviewer’s comment and have included this idea in current line 135-136.

REVIEWER COMMENT : Lines 135-137. When dealing with deterministic hazard as-

sessment is this area, are there non-seismic tsunami events that are worth of consideration? Landslide-tsunamis, for example, usually affects short coastal stretches but their effect can be highly destructive.

RESPONSE: There are other possible sources of generation, as evidenced in previous studies (for example, Heidarzadeh and Satake, 2014a and 2014b and 2017; Suppasri et al., 20106). However, in this study, we have just considered potential earthquake sources for the tsunami risk assessment. Landslides, as mentioned by the reviewer and some of the references cited, have a local effect (even if highly destructive) and the efforts and resources needed to analyse them for the entire country go beyond the scope of this study. We have slightly modify the sentence in current line 127 to make it clearer that in this study we have considered only earthquake sources.

REVIEWER COMMENT : At Line 140, an early warning system establishment for Oman is cited. Is it working, in phase of realization, or just an intention at the moment?

RESPONSE: The early warning system is currently working. We have slightly modified the sentence in current line 146-147 to specify it. Please, see also the link provided for additional information: http://www.unesco.org/new/en/media-services/single-view/news/oman_launches_an_early_warning_system_to_address_natural_dis/ http://www.helzel.com/files/432/upload/Pressreleases/2015/NMHEWS-Oman-2015.pdf

REVIEWER COMMENT: In the paper the expression “inundation depth” is used repeatedly (for example in the definition of the drag level, Line 145): if it refers to the height of the water inundating the land (meaning the difference between the elevation of the water top and the topography) it is better to use the expression “flow depth”.

RESPONSE: We have changed the expression “inundation depth” to “flow depth” along the document (and figure 4). We have also referred to it as inundation depth when is first described (current line 152), since there are some works that already call it that

way. Please, see changes in current lines 87, 151, 157 and 214 and Fig.4.

REVIEWER COMMENT: When dealing with building vulnerability assessment, the most diffused quantities in tsunami science are flow depth H, water velocity V, and momentum flux (defined as HV2), the last accounting for the energy of the incoming wave. However, specify better in Lines 145-150 that drag force is for human dimension and flow depth for building one, and justify why you did not use momentum flux.

RESPONSE: As it is properly expressed by the reviewer, different tsunami hazard variables may be applied to assess building vulnerability. In the case of the present study, we based on the works developed by Tinti (2011) and Valencia (2011) where the flow depth-building damage relationship is analysed to develop fragility curves, based on post-tsunami observations that consider different building typologies (structure, construction material, number of storeys). This is explained in current lines 157-159 and 214. The use of flow depth variable for infrastructure dimension and depth-velocity product (drag level) for the human dimension is explained in the “risk assessment” section, current lines 204-218.

REVIEWER COMMENT: What do you mean with “exposed people and infrastructures” (Table 1 and Line 172)? Are they counted considering their inclusion in the flooded area? Explain and specify better.

RESPONSE: By exposed people and infrastructures, we are referring to the people, buildings and infrastructures located in a flooded area, as described in current lines 88-89. A sentence has been included in current lines 181-182 explaining better the exposure.

REVIEWER COMMENT: Concerning Risk Assessment: how are hazard components for human and building components estimated? Is the flow depth over each building computed as the maximum water height? And what about drag force? Is it computed at each time step and then the maximum selected, or is it simply the product of maximum flow depth and velocity for each element? Consider that these do not occur necessarily

at the same time.

RESPONSE: Yes, you are right and this is a very good question. Hazard variables are calculated at each time step and the maximum is then selected: h(max) or (h*u)max. There is another scientific article detailing this process in preparation and will be submitted this month. A brief explanation has been included in current line 149.

REVIEWER COMMENT: Lines 198-199: how are the two risk dimensions weighted?

RESPONSE: The whole analysis is performed through a human-centred perspective. In this sense, a slightly higher weight has been considered for the human dimension.

REVIEWER COMMENT: Line 266: again about exposure, here concerning HS. How is it measured? Is there a threshold for the flow depth, or is it sufficient the inclusion in the flooded area in order to consider the element "exposed"? Specify and clear better this point. RESPONSE: It is sufficient the inclusion in the flooded area. No threshold has been established. We have included a clarification in current line 277.

3. RESULTS

REVIEWER COMMENT: Line 302. When you speak of "flooded area", do you consider a flow depth threshold? Or is it sufficient that the area is simply covered by water, though few centimetres?

RESPONSE: No threshold has been established.

REVIEWER COMMENT: Lines 376-383. Can you provide some explanation of the fact that a detached breakwater would increase wave elevation on the coast? Are there some hydrodynamics effects justifying it? In Figures 12c and 12d probably it would be better to evidence where such prevention measures (breakwater and artificial dunes) have been placed.

RESPONSE: The presence of a break water modifies tsunami height and energy flow direction, generating an accumulation of energy in the leeside, focusing the affection

to the coast and increasing the flooded area. A brief explanation has been included in current lines 393-394. Figures 12c and 12d include now location of breakwater and potential artificial dune location.

Technical Corrections

ABSTRACT

REVIEWER COMMENT: the first sentence [Lines 9 to 11] is repeated almost exactly in the Introduction [Lines 24-25], change one of the two. 1. INTRODUCTION REVIEWER COMMENT: Line 32. "most exposed to MSZ effects"

RESPONSE: Done, please see current line 37.

REVIEWER COMMENT: Line 39. "for all the components contributing to the risk"

RESPONSE: Done, please see current line 44.

REVIEWER COMMENT: Line 48. "have to be taken" instead of "are to take"

RESPONSE: Done, please see current line 55.

REVIEWER COMMENT: Line 72. Remove comma after "or"

RESPONSE: Done, please see current line 79.

2. METHODOLOGY

REVIEWER COMMENT: Line 125. "to" instead of "and"

RESPONSE: Done, please see current line 131.

REVIEWER COMMENT: Line 127. Remove "quake", repetition with Line 126.

RESPONSE: Done, please see current line 132.

REVIEWER COMMENT: Line 128. "...COMCOT (Wang, 2009), which solves shallow water equations using Okada model..."

RESPONSE: Done, please see current line 135.

REVIEWER COMMENT:Line 129. Provide citation for Okada model

RESPONSE: Done, please see current line 135.

REVIEWER COMMENT: Lines 162 and 164. Remove comma after “are”

RESPONSE: Done, please see current line 171 and 173.

REVIEWER COMMENT: Line 185. Describe in few words (or include a reference about) the min-max method.

RESPONSE: please see current line 195 and 592.

REVIEWER COMMENT: Line 253. “It is summarized”

RESPONSE: Done, please see current line 263.

REVIEWER COMMENT: Line 279. “On the one hand”

RESPONSE: Done, please see current line 291.

REVIEWER COMMENT: Line 280. “where flooding occurs on a regular basis, at least annually” this seems to mean that these areas are affected by tsunami at least once per year. Is “flooding” meant in general, by storms, river flooding or other? Reformulate better.

RESPONSE: Done, please see current line 292.

3. RESULTS

REVIEWER COMMENT: Line 296. Separate with space “assessmentand”

RESPONSE: Done, please see current line 309

REVIEWER COMMENT: Line 297. Separate with space “Omandeal”

RESPONSE: Done, please see current line 309.

REVIEWER COMMENT: Line 299. Separate with space “processdescribe”

RESPONSE: Done, please see current line 312.

REVIEWER COMMENT: Line 309. Remove “it”, the subject Wilayat Al Jazir (is already present)

RESPONSE: Done, please see current line 322.

REVIEWER COMMENT: Line 310. Remove “the” before “8%”.

RESPONSE: Done, please see current line 323.

REVIEWER COMMENT: Lines 361-362. Move “is located” at the end of the sentence.

RESPONSE: Done, please see current line 376.

REVIEWER COMMENT: Line 423. Add comma after “tsunami-prone flooded areas”.

RESPONSE: Done, please see current line 441

REVIEWER COMMENT: Line 438. Remove comma after “prioritizing”.

RESPONSE: Done, please see current line 456.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-448/nhess-2017-448-AC2-supplement.pdf

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