Tsunami evacuation modelling as a tool for risk management: application to the coastal area of El Salvador

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Authors' response to Anonymous Referee #2

First of all we would like to thank this Referee for accepting to review this paper and for the valuable and constructive comments provided. According to the suggestions made by the Referee, we have carried out an extensive revision of the paper and we proceed in this document to answer all the comments, the referee's comments being presented in black bold font followed by the authors' answers in blue font.

Referee #2

Abstract:

Please include a sentence to indicate that the framework has been applied to the El Salvador case study, demonstrating application to locally-specific response times and population to determine optimal evacuation locations for the study area.

A reference to the case study has been included in the revised paper.

Manuscript text –required corrections:

P.2171 ln20: Section 2.1 would benefit from the inclusion of a sentence to explain why hazard assessment is not dealt with in more detail here. It is fine that this paper focusses on the evacuation planning method, not the hazard assessment, but please clarify this point and direct the reader to a methodology for the hazard assessment, for example earlier papers in the same project that are related to this El Salvador analysis.

This has been clarified in the revised paper.

P.2172 ln.8: Please provide some further explanation of 'illiteracy'. Do you mean illiterate specifically for not understanding written materials or illiteracy in terms of hazard awareness and protective appropriate actions?

It refers to the understanding of warning messages, this being clarified in the revised paper.

P.2173 ln.1-8: Please clarify whether the 'security level' in the medium and high security zone descriptions is defined by elevation, distance from the coast, or both.

The security level is defined by elevation, this being clarified in the revised paper.

P.2175 ln.22: The reaction time of 15min for the whole population is an oversimplification – the whole population would not evacuate at the same time. This should be acknowledged as such in the text, with an explicit justification of the use of this value. (also clarify at p.2183 ln18)

According to this comment, the use of this reaction time is explained and justified in the revised paper.

P.2177 ln.9: Please include clarification of whether the slope calculation accounts for direction of travel. I.e., does slope slow evacuation regardless of whether the evacuee is travelling uphill or downhill. You should provide the equation to show how you adjust the speed to account for effect of slope.

The slope calculation considers the elevation of the origin and destination points, not accounting whether the evacuee is travelling uphill or downhill and how many times the slope changes by evacuation route. The equation is provided in the revised paper.

P.2176 ln.20: Clarification is required on the use of 'evacuation origin points'. Are all people from one community assumed to originate at a single point or does each point represent an individual or family/instutional group?

A clarification regarding the evacuation origin points is provided in the revised paper. These points are located in every road intersection inside the flooded area and based on the spatial analysis of the distribution of population.

P.2178 ln.21: Please explain the reason for choosing a response time of 30 minutes. As this is part of the paper is presenting the framework, it should be made clear here that this value should be altered according to the context / case study area based on modelled tsunami arrival time or minimum potential response time for the local area. This is required to avoid readers assuming that 30 minutes is a suitable time threshold in all cases. It is then appropriate in your case study section to use a particular response time based on the local context.

According to this comment, this part of the paper presenting the framework has been maintained "generic". Therefore, the reference to the 30 minutes has been removed from the section.

P.2178 ln22: Please include a more detailed explanation of the 'iterative location' process. In order to properly optimise the tower locations, steps 2, 3 and 4 (and an additional step: calculating the number of people who can travel to the tower given the calculated distance) should all be carried out for each iteration (each potential tower location) in order to optimise the location of towers in each area. As it stands, the text does not fully explain the method used so it is difficult for the reader to understand whether optimisation is carried out correctly. Do you a) choose one tower location per area and iteratively add more tower locations in that until evacuation demand is satisfied (i.e. let the optimisation determine the number of towers and their location), or b) iteratively alter the location of a single tower in each area until evacuation demand is satisfied (i.e. pre-determine that only one tower should be located in each area)? State the basis on which you determine the optimal location – presumably by the tower location that can be reached by maximum number of people in the area, but you should state this explicitly.

A detailed explanation of the iterative process has been included.

The iterative location of towers at strategic points in the area is based on the number and distribution of people along the flooded area, the tsunami arrival time at the coastline, the geomorphologic characteristics of the territory and the subsequent effects on the tsunami. The iterative process include the steps iii), iv) and v) (calculation of the arrival time of the tsunami, calculation of the time available for evacuation at that point, and calculation of the distance that can be travelled) in order to optimize the location of towers, i.e. based on the obtained results for each tower the initial position is maintained or modified to achieve better results in terms of number of people reaching the shelter (with special attention to the people located seaward of the shelter). The optimization determines the number of towers and their location.

P.2178 ln23: The use of tsunami arrival time at the location of the vertical evacuation shelter neglects the fact that the population located seaward of the evacuation shelter have less available evacuation time than quoted for the tower. For example, shelter 3 in figure 12: the majority of evacuation origin points are located seaward of the arrival. For a more conservative estimate of the available travel time, the arrival time at the coast should be used. The justification of using arrival time at the tower location, rather than arrival time at the coast should be stated.

A justification for the calculation of the arrival time at the tower (case A) instead than at the coastline (case B) is presented in the revised paper. The authors believe that the case B could be more conservative in terms of available evacuation time for the population seawards of the tower; however considering a lower tsunami arrival time for the tower means a lower time to reach it and consequently a smaller reception distance, a closer location seaward, an evacuation direction towards the sea, and a smaller amount of evacuees by tower. This forces the decision maker to build more towers not context-specifically-designed instead of optimizing their location and size. The same tsunami arrival time could be assigned to different towers, hindering an adequate design according to the expected number of evacuees. Besides, a high amount of towers would imply a high budget assignment to this issue, which is usually politically or economically not easy, resulting into building less towers than the ones needed for the case applied (case B). The case A calculates the arrival time at the tower providing the real reception distance and time to reach the tower; the location of the tower being previously chosen based on the time the coastal communities need to successfully evacuate. Using the real situation for each tower permits the iteration to select the appropriate locations and the design of the tower according to the real number of evacuees. Case A implies less towers better context-specifically designed.

P.2179 ln10: Section 2.6 reads as though it is a summary of section 2. Please update the title to make it clearer that this is a summary. The modelling phase should be included in this section, to give a complete summary of the section.

There was a mistake in the text. Now the modeling phase is mentioned.

The authors acknowledge that this section seems to be a summary; however, it refers to the Planning Phase, which uses the information provided by the Analysis and Modelling Phases. Accordingly, the title has been maintained.

P.2179 ln20: please provide a reference for the catalogue of historic tsunami to have affected this area. What proportion of tsunami that have affected the coastline been local, regional or distant?

This information has been included in the revised paper.

P.2180 ln18-24: A reference is required for the work on the deterministic hazard analysis. Please state more earthquake parameters to describe the source earthquakes – as a minimum state the range of magnitudes used, and whether are these local /regional / distant events

This information has been included in the revised paper.

P.2180 ln22: Please make it clear that drag is calculated as: flow depth * velocity, and that the maximum potential drag is the required parameter for the analysis.

The drag value at each point of the grid and for each event modeled is obtained by multiplying the speed value by the depth value at each instant, and calculating the maximum value of the product, i.e. max (h * u), which is different than considering the maximum value of the speed at that point (i.e. maxu * h). The drag value at each point of the grid for the aggregated case (23 worst credible events) is the maximum drag value obtained among the 23 events.

This has been clarified in the revised paper

P.2180 ln22: (and figure 4). Maximum wave height elevation is useful for empirical estimation of run-up from wave height at the coast when no inundation modelling has been conducted, but in this case, the presentation of flow depth makes this measure somewhat redundant. Figure 4 would be more useful to the reader if maximum flow velocity was shown, rather than maximum wave height level. Please amend the legend to clarify that the bottom map shows maximum drag.

Figure 4 has been modified according to this comment.

The case study presented does not incorporate any estimation of the number of people in the hazard zone. It does not present any discussion of the numbers that can be saved at each shelter site, therefore the required capacity of the shelters (although this general concept is mentioned in the text). In order to complete the case study, such values should be cited.

These values have been included in the revised paper.

Manuscript text – additional suggested corrections:

P.2164 Ln.22-23: suggested change 'identifying' to 'identification of'

This expression has been changed in the revised paper.

P.2166 Ln.23: A reference for FLOODsite project (2009) is not included in reference list

The reference has been included in the revised paper.

P.2167 In.6: 'Bc Hydro' should read 'BC Hydro'

This expression has been changed in the revised paper.

P.2169 In.10-17. I would argue that this is surplus to requirements, particularly the final sentence, which is too vague.

This paragraph has been modified and reduced according to this comment.

P.2169 In.22: There seems to be a word missing – should this read '. . .therefore translates into benefits. . .'?

The word has been included in this sentence.

P.2171 In.23: The phrase 'tsunamis with greater or lesser affection to the study area's coast' should be changed to something like 'tsunamis that affect the coast to a greater or lesser extent' or 'tsunamis with variable impact on the coast'. Please update all instances of this in the paper.

This phrase has been modified in the revised paper.

P.2171 In.24: 'distant, intermediate and close sources' are usually referred to as 'distant, regional and local sources'. Please consider amending this.

These concepts have been modified according to this comment.

P.2172 In.19: Please consider changing 'not-flooded areas' to 'areas that are not flooded'

This has been modified accordingly.

P.2173 In.16: Change 'epigraphs' to 'paragraphs'

This has been modified accordingly.

P.2179 In3-4: Please update your subscript notation to English for consistency.

There was a mistake in these words. They have been translated to English.

P.2180 In3: A map of El Salvador indicating the location of the western coastal plain would benefit international readers unfamiliar with the country location, coastal orientation to local fault zones and epicentres of past local earthquakes.

A map has been included in the revised paper.

P.2180 In12: Please change 'affection to the country's coast' (see earlier comment)

The expression has been modified.

P.2180 ln14-16: Consider altering 'intermediate' and 'close' sources (see earlier comment)

These concepts have been modified according to earlier comment.

P.2181 ln13: Please change 'below 10' to 'below the age of 10' or 'below 10 years old' for clarity

This has been modified.

P.2183 ln6: Please update 'time' to 'response time' for clarity

This change has not been adopted as the response time includes the 3 paragraphs (13 min + 17 min + 15 min) and not only the first one. A wrong comma has been deleted to make it clearer.

P.2184 ln11: To be consistent with previous terms used in the manuscript, evacuation time (not evacuation speed) is a function of a person's speed and distance travelled.

The expression has been modified.

P.2185 ln1: Use 'arrival time' instead of 'arrive time'

The expression has been modified.

Conclusions:

The conclusions should refer somewhere to the application of the framework to the case study.

The conclusion includes now a reference to the application of the framework to the case study and some of the obtained results.

P2186 ln17-27: This section introduces several new personal characteristics to the vulnerability analysis, which were not mentioned previously in section 2.2. The full list should be presented in section 2.2 and a brief list presented in the conclusion.

This paragraph summarizes the information provided in Section 2. The full list was provided in Table 1. A reference to this Table has been included in the Conclusions to clarify this point.

References:

Please include web addresses to direct readers to the source of: Aboelata and Bowles 2005, BC Hydro 2004, Cano 2011, OECD 2008, Scheer 2011a.

Web addresses have been included in the revised paper.

Figures/Tables:

Figure 2: The caption should be more descriptive, with respect to describing the components of total evacuation time and the difference between the top and bottom images

The caption has been completed.

All maps: The scale is not legible on your maps, even when looking at a zoomed-in electronic colour copy. These should be made larger for inclusion this manuscript if at all possible.

The scale has been enlarged for all the maps.

Figures 4-5: The legend text on maps in the top row is difficult to read and should be enlarged if possible. I appreciate the time required to update some maps, so if it is not possible in this case please consider this for future publications

The mentioned legends have been enlarged.

Figure 8: Please include in the caption, the event used to determine the arrival times. What does the '(5 min.)' refer to in the legend? The legend is missing value between 20 and 25 minutes.

The caption of this figure includes now the event used. The legend has been also corrected.

Figure 10: Should 'T45' be 'RT45' as it is referred to in-text?

This has been corrected in the revised paper.

Figure 11: Caption requires further description to explicitly explain what this is showing.

The caption has been improved.

Figure 12: While location of shelter 2 and 3 makes sense given the concentration of evacuation origin points, the reception area for shelter 1 has only 1 evacuation origin point in the reception area, therefore I struggle to see why this is an optimal location. This relates to the iterative location method / statement of population values in the study area. In-text explanation of the iterative process of choosing an optimal location should also include an explanation of how shelter 1 came to be the optimal location for this area. This figure would benefit greatly from reporting the number of people estimated to be in the reception area for each shelter.

The revised paper includes this explanation and data about the number of exposed population.