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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Tsunami fragility curve using field data and numerical simulation of the 2015 tsunami in Coquimbo, Chile" *by* Rafael Aránguiz et al.

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- Title: Please consider adding the part "application of the developed fragility curves" in your title R: the title will be modified according to suggestions of both reviewers, for example: "Development and application of tsunami fragility curve of the 2015 tsunami in Coquimbo, Chile".

- Abstract: Please also specify the earthquake magnitude of both the 2015 and future events as well as add a short explanation about the comparison of the developed curves against Dichato. R: the abstract will be modified according to suggestions, such as we add earthquake magnitudes and short explanation about the comparison with

fragility curve of Dichato.

1.- Introduction: -Please make sure that you use the same name, 2015 Illapel earthquake (same in Fig.1) throughout the paper. R: The name of the 2015 Illapel earthquake will be modified and check throughout the text.

- In the last sentence of this section, your objective is only about two sentences. I would suggest to write them clearly using bullets and separate them from the literature review. R: The introduction will be modified as suggested, such that we clearly write the objective in a separate paragraph from literature review.

- There are some recently published works about fragility curves and their application that should be mentioned: Song et al. (2017), Charvet et al. (2017), Macabuag et al. (2016), Suppasri et al. (2016), Fraser et al. (2014) and Wiebe and Cox (2014) R: recent papers on fragility curves and damages estimation suggested by the reviewer will be checked and included in both introduction and discussion.

2.- Study Area - Please also clearly state the topographical characteristic of the study area, plain area similar to Sendai? R: More topographical description will be added about the study area

3.- Developing fragility curve. - What kind of the field data used as I can only see the recorded waveforms? Did you also measure inundation heights/depths from the field survey? If so why didn't you used them for your model verification in addition to the recorded waveforms? R: We used both tsunami waveforms and inundation hight measurements. As explained in the paper, the tsunami waveforms from a DART buoy and two tidegauges were use to select the best tsunami source model. Then, the tsunami inundation heights measurements were used to select an appropriate roughness coefficient in order to fit both inundation heights and inundation area. We will explain better this methodology in the text in order to be sure the readers do not misunderstand it.

- 3.1 Data: What is the average numbers of stories of these 568 buildings, 1-2 stories?

R: The houses were 1-story buildings on average. Few of them were of 2 stories and the typical configuration is the first floor of masonry and the second floor of wood. Since the flow depth was less than 3 m, and it did not exceed in height 1-story buildings, we thought to analyze all structures as the same type of buildings. It will be easier the comparison with Dichato.

- Please add the photo taken date for Fig. 2. R: We will add the photo date in the Figure caption. All photos were taken on September 22nd of 2015, only 6 days after the event.

- What are structures for the two houses in Fig. 2c and 2d? R: we added a description of the structures in Figure 2. Both structures in 2c and d were originally made of confined masonry. The structure in figure 2c was being repaired at the moment of the field survey with masonry made of concrete blocks.

- How did you confirm that the surveyed houses are the original damage condition or you evaluated the damage by asking all house owners? Was the almost damage from earthquake because of the retrofit/lesson from the 2010 event? R: The field survey took place only 5 to 7 days after the event and just few of the structures were already under reconstruction, therefore, the damage observed was assumed to be the one caused by the tsunami. According to official reports, the damage to structures due to the earthquake was very limited in Coquimbo area, and most of the damage observed was non existing or light damage only (few cracks). To confirm this, the authors had the opportunity to compare damage on inundated and non inundated houses in Coquimbo, in order to be sure that the structural damage to inundated houses was due to the tsunami. This is another reason why we used two-level damage scale. Doing this, we also wanted to avoid including light damage (due to the earthquake) as tsunami damage. We will add some paragraphs to explain this procedure in the paper

- It was possible to developed fragility curves for more than two damage levels. In Suppasri et al. (2012), they developed the curves for four damage levels using less

than 200 buildings. R: Yes, it would have been possible. Unfortunately, when we made the field survey, the main goal was to develop the fragility curve to assess the damage in case of future event as well as to be compared with the existing fragility curve of another town in Chile, Dichato (Mas et al., 2012), which has only two damage levels. Therefore, we classified the structures according to two damage levels only. In addition, as explained above, since the earthquake generated no or light damage to structure, the use of two damage levels was to avoid the classification of light damage due to earthquake as tsunami damage.

- You may change the word from “surviving” to other words such as remaining, not destroyed, etc. Buildings are not living things, thus the word “survive” sounds not so suitable in my opinion. R: The word “surviving” was changed by “not destroyed”

- Please add some photos of the buildings as example of your damage levels, destroyed and not destroyed. Washed away building should be also included in the “destroyed” damage level. No washed away buildings in this 2015 event? R. We will mention the damage level of the structures in figure 2. In addition, there were some washed away building, and we will include more pictures of those cases.

- 3.2 Inundation depth: It is confusing if you used your measured inundation heights during the survey for your inundation simulation or just the recorded waveforms for the source verification? If you have all surveyed inundation heights for each building, you can then develop fragility functions using the actual maximum flow depth from the field survey and maximum flow velocity and hydrodynamic force by making use of the numerical simulation. R: Unfortunately, the surveyed inundation heights were not for each building. The measurements were taken in several places in order to interpolate the flow depth as it was made in the paper of Mas et al., (2012) on Dichato. However, due to the absence of the tsunami traces on the wetland and at locations of washed away houses, it was not possible to obtain a representative interpolated inundation area. Subsequently, we decided to run tsunami numerical simulations and validate the results by means of the K and kappa coefficients using our tsunami height

measurements. We will explain better this methodology in order to avoid confusion to the readers.

- Please make clear about this in this section. Please use the original reference for K and Kappa (Aida, 1978). R: we will use the proper reference as Aida 1978.

- 3.3 Fragility curves: Similar to section 3.2 that I would like to encourage the authors to used their simulated maximum flow velocity and hydrodynamic force to also develop the fragility curves as successfully made by previous studies (Koshimura et al, 2009, Suppasri et al., (2011) and Gokon et al., (2014)). These curves using flow velocity and hydrodynamic force can be used to explain in your section 3.4 why your study area have lower damage probability (far and protected by railway embankment). Even if the same flow depth, but you may be able to explain that the flow velocity and hydrodynamic force is much lower in your area. R: As recommended by the reviewer, we added new fragility curves using flow velocity and hydrodynamic force. In addition, we also added a map of maximum flow velocity and hydrodynamic force in Coquimbo area in order to explain better the tsunami damage.

- 3.4 The title of the section is wrong? Should be Comparison of the developed fragility curves or something? R: Yes, the title was wrong and it was changed to the correct one: “Comparison with existing fragility curves”

- I suggest to use bullets or subsection to compare your curves with 1) Dichato first, 2) then Okushiri and other part of Japan and 3) other parts of the world (Why didn’t you also compare with Samoa and Thailand?) R: we will improve the subsection according to the suggestion. We did not use the curves of Samoa and Thailand due to the fact that the building material was different (RC). We only used curves from similar construction material. We will add a sentence to explain this in the text.

- Can you spilt the data and develop another one or two curves for 1-story or 2-story only? Then you can show that the damage of the mix stories is lower than 1-story only or higher than 2-story only. R: We agreed this analysis could be useful, unfortunately,

we did not classify the structures according to the stories since they were very similar in size and material. In addition, we wanted to compare the results with the fragility curve of Dichato, which also considers one type of structure. Moreover, the main task of the paper was to develop a fragility function to assess tsunami damage in case of possible event in the future. The comparison of several curves according to number of stories could be out of the scope of the paper. However, we could perfectly add a comment on this based on existing literature.

- 4.1 Source model: Did the event in 1849 a tsunami earthquake? Why such event is not necessary to include in this study? R: R: we added details on the 1849 event in the current draft, and this event is very important when segments of possible events were defined. Unfortunately there is no enough information about this event, thus a source model is defined.

- Please also write that you used earthquake magnitude (8.2-8.5) in the explanation not only in Fig. 9. R: We will add the magnitudes of the possible events in the text and not only in the figure 9.

- 4.2 Proposed scenario: It will be very useful for readers if you could add one figure showing the comparison of the simulated flow depth of 2015 tsunami against the proposed scenario. May be the values shown in the map can be the difference between the proposed scenario and the 2015 tsunami (i.e. Fig. 10(center-S1) minus Fig. 7a). Then the readers can be easily seen that where we might expected greatly increase of the flow depth from the future event. R: good idea. We will add another box in Figure 11 to show the difference of 2015 event and the S1 event.

- Characteristics of the maximum flow velocity and hydrodynamic force can be also discussed and support your explanation at the end of this section R: Yes, since we will include new fragility curves using velocities and hydrodynamic forces as well as maximum velocity field maps, we will add more discussion based on these results and existing literature.

4.3 Tsunami mitigation measures are deeply discussed by Strusinska-Correia. (2017) and Suppasri et al. (2016). R: we will add some sentence on the possible mitigation measures based on the literature suggested by the reviewer.

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