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Reply on RC1

Jean Roger et al.

Author comment on "The M_w□7.5 Tadine (Maré, Loyalty Islands) earthquake and related tsunami of 5 December 2018: seismotectonic context and numerical modeling" by Jean Roger et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-58-AC1, 2021

In the following, we have carefully answered (in bold writing) to the questions of the 1st referee (RC1 in italic writing).

This paper presents an analysis of the Mw 7.5 earthquake and related tsunami occured on December 5th, 2018. The analysis included description of the source, field survey and tsunami numerical simulation. My major concern is that the paper does not have a clear focus and it is difficult to find one main idea throughout the paper. Is the focus the earthquke? the tsunami field survey?, the numerical simualtions? validation of numerical modes? or the analysis of tsunami hazard? I recommend to focus on the tsunami behaviour in order to explain why a small event can generate a large tsunami.

- **This paper deals with the December 5, 2018 earthquake AND tsunami. It is important to discuss the complex tectonic background of the region first, as well as the history of earthquakes/tsunamis having affected New Caledonia. Also, working on tsunami modelling doesn't prevent to relate to reality and deal with field observations. This event, even if small in comparison to other tsunamis in other regions of the World, is of main concern for New Caledonia, Vanuatu and nearby countries and all the aspects must be presented to understand the issues.**

Then, the field survey, tide gauge data and numerical simulations can be used to explain that phenomenon. I do not believe that with one event you can make an analysis of the implication for tsunami hazard. It could be mentioned in the discussion, but as the paper is right now, it is not possible to include it in the title, unless the focus of the paper is the tsunami hazard. In that case, more information and state of the art on tsunami hazard in New Caledonia should be mentioned in the Introduction as well as your current contribution.

- **The paper does not focus specifically on tsunami hazard assessment but presents how one event, which shows quite important tsunami amplitudes (comparing to the history of tsunamis in New Caledonia) and is the only tsunami recorded on all local tide gauges, can be useful to validate the way the tsunami hazard assessment is/will be done for the archipelago. That's why we used "implications for tsunami hazard assessment" in the title, to provide information to the reader how one event like this can help in a place where so few events are available, because of very recent history (< 150 years).**

Another concern is related to tsunami numerical simulations. Only uniform slip distribution is used, but it has been demosntrated that uniform slip may underestimate the hazard. See for example Melgar et al 2019; Carvajal and Gubler 2017; González et al. 2020; Geist and Dmowska 1999. This could be an explanation why simulated tsunami waveforms at tidegauges are not in agreement with tide gauge records Would it be possible to use a nonuniform slip distribution model? It would be desirable to propose some finite fault models of the earthquake by means of seismic records, thus seismic parameters such as strike, dip and rake are properly defined.

- **We have tested the heterogeneous slip distribution provided by the USGS (https://earthquake.usgs.gov/earthquakes/eventpage/us1000i2gt/finite-fault) and because there are no substantial differences with the uniform slip distribution on the tide gauge records we had decided not to show the results in the paper. In this particular case, the uniform slip distribution shows higher amplitudes than the non-uniform one on tide gauges. Also, the solution proposed by the USGS does not fit at all with the empirical relationships between earthquake parameters and seismic moment proposed in the literature for such rupture (Strasser et al., 2010; Blaser et al., 2010, etc.).**

The paper does not have an introduction, and the main objective of the paper is not clearly described. In addition, the section 1 "General Setting" is too long to be an introduction. this section should be compressed and be part of a "Study area" section. It is very important to define the focus of your paper, then, define which information regarding the tectonic setting is relevant.

- **We agree that the introduction is long, but it is important to set up correctly the complex tectonic background of the region as well as dealing with the historical events especially for people not familiar with this region. We propose to change the plan of the manuscript a bit, moving that information about tectonic background in a dedicated part, reducing the size of the introduction and making the focus of the paper clearer.**

The title mentioned the "implications for tsunami hazard", but none of the sections mentioned anything realted to current tsunami hazard analysis in the study area. If the focus of your paper is the implications for tsuami hazard, you should present the state of the art of tsunami hazard in New Caledonia, such that the scientific gap and your contribution are clearly described in the introduction.

- **Not necessarily: the implications could be for a future study of tsunami hazard assessment, for example, how we plan to use this event as a basement for updating the actual scenario database.**

Another minor comments are the following

- Figure 1. Please add a general map here, such as the left hand side map in Figure 3.

- **We will add a general map here as requested on an updated version of the figure.**

- line 46, it says "pressure gages", but in other places, such as line 425 it says "tide gauges". Use gage or gauge, but not both.

- **This is a typo mistake, it should be "gauge"**

- section 1.1 and 1.2 report significant amount of information regarding past earquakes, but the point is not clear. Would it be possible to combine Figure 1 and 2 and summarize

the important facts only?

- **Historical seismic activity of the region is shown on Figure 1 with the identification of events who generated a tsunami recorded in New Caledonia. Figure 2 is focused on the different seismic crises which occurred in the specific area of the 5 December earthquake and illustrated the special tectonics of the area. Figures 1 and 2 are complementary.**

- line 161 indicate a finite fault model from USGS. Why didnt you use this model? You only mentioned this model, but do not explain why it is discarded.

- **This model has been used and compared to the other simulations but does not provide better results. The objective was to show that a simple fault plane with uniform slip can produce results in the same order than the observations/records in an operational aspect. Anyway, we understand that after more than 2 years since the earthquake occurred, people would like to see results obtained with more detailed sources and thus, it will be added in the new version of the manuscript.**

- Figure 3. It is difficult to read this figure. I recommend to improve it, for example, add also field survey data to this figure, and add the magnitude of the measurement (the number) and not only a color. Instead of a color, add insets with the tidegauge records, thus we could see maximum amplitudes and the tsunami behavior as a function of time.

- **We agree that the figure 3 is a bit difficult to read and should be improved; it is a good idea to add the field survey/observation values to the tide gauge maximum amplitudes. Concerning the tide gauge records they are already shown on figure 8.**

- Section 2.2.2. All measurements and maximum amplitudes reported in this section should be listed in a table with longitude and latitude coordinates. In addition, measurementes should be indicated in Figure 3, as mentioned in a comment above.

- **We agree that a table would be more efficient for the readers; it will be added in the new version of the manuscript.**

- Fiure 5, please draw the coastline to see better the islands.

- **The coastline will be added in the new version of the figure.**

- line 292. Please explain how L=80km and W=30km were defined. The model from USGS used L=160km. How did you come up to 80 km? did you use a scale relationship? if so please explain which ones.

- **The values have been obtained using the empirical relationships from Strasser et al. (2010) and Blaser et al. (2010). To fit the results of these 2 studies, and in agreement with the geological/tectonic context of the region, a Mw = 7.5 normal faulting earthquake could be associated to a rupture showing length L~80 km (maximum value obtained with all the relationships) and width W~30 km (minimum value obtained with all the relationships). We agree that the paragraph dealing with this must be included in an update of the manuscript.**

- lines 285 to 295. Several seismic parameters are presented here, however, in line 353 two strike anlges are mentioned, but they were not mentioned earlier. I suggest to add a table in section 3.1.2 with all seismic parameters used in the numerical simulations,

including the two strike angles and depth.

- **We agree with this remark and must add a table gathering all the parameters in a further version of the manuscript.**

- lines 336 to 340. You described a sensitivity analysis regarding the kinematic tsunami initial condition. I understand that you used a linear variation during 50s with time step of 1s, but previously you mentioned that the USGS model has 3 patches and it website shows a rate of moment release with 4 peaks during the 50 s. Therefore, it is inconsistent.

- **It is right. Since this remark, we managed to simulate the complex and dynamic seabed deformation as suggested from the USGS dynamic rupture model and did not see any substantial change compared with the USGS static model.**

Please explain why you made a sensitivity analysis. Why not simply using a static sea bottom deformation by means Okada formulation?

- **There is no sensitivity analysis about the question of how to model the deformation since we use the default behaviour as implemented in schism: a rupture from the seabed propagating through the water column. Seabed motions are driven by the Okada's solution.**

- line 353. Please explain why you used these two angles in section 3.1.2.

- **Explained in the text (see line 158 to 160): the strike from USGS and GCMT was not the same and we have chosen the GCMT solution because it is more in accordance with the geological knowledge of the region (bathymetry, identified structures, etc.).**

In addition, in line 159 you mentioned several combinations of parameters according to different observatories, but later you select only one dip and rake ablges, and vary the strike angle. Please explain better the assumtions in section 3.1.2. from lines 291 I understand that you will use the GCMT parameters (312°, 36° and 90°) but then you also used 298° for strike angle.

- **We only show one of the multiple sensitivity tests we have run during the process. This one produced the most important variation of main energy path orientation and the maximum amplitude on the tide gauges.**

- line 342. It says that simulations have a slapsed time of 3 h, but it may be short considering the distance from the source to the points of interest and resonance effects, as mentioned in line 250. Did you check any resonance effect?

- **Yes we did. It does not provide any interesting results.**

- Figure 6. I suggesto to draw the trech in all figures in order to better sea differences between tsunami source models.

- **This will be added in a new version of the manuscript.**

- lines 372-420. results here are only descriptives, and no analysis nor discussion on tsunami behavior is presented. Please, according to your results and analysis, explain why you have amplification (see lines 378, 379, 383, etc).

- **The discussion of the results is provided in the Discussion section (part 4)**

between line 427 and line 463.

- lines 396 to 399. It says that the modelling is not able to reproduce the tide gauge record in terms of arrival time and amplitude, but no analysis nor discussion are presented in order to find possible causes. Please explain possible causes such as grid resolution, bathyemtry errors, fault location (fault model is closer to the tide gauge than the real rupture), uniform v/s heterogeneous slip, etc?

- **As said above discussion is presented in Discussion section (part 4).**
- **After revisiting the nonuniform and dynamic USGS model, we also noticed a possible degradation in arrival times compared with our custom fault model, which is more consistent with the local tectonic context. Impacts of fault location will be discussed in the revised version of the manuscript.**

- Figure 8. only two hours of numerical simulations are shown. If you simulated 3h, please show the 3 h. It seems that the third wave in figure f is larger than the second, but it is not shown. In addition, adjust the vertical scale in figures g an h, thus the whole amplitude is shown in the plot.

- **We agree with this comment and we will show the results until 3 hours in a new version of the manuscript. Vertical scale will also be fixed.**

- The paper needs a Discussion section, thus all results and implication in tsunami hazards are discussed. In addition, you can discuss whether the phenomena observed here (amplification, defocusing, resonance, etc) have been observed in other places, thus you can explain the tsunami bahaviour in the current event, and , hopefully, explain what could happen in future events.

- **Discussion section available (part 4) between line 427 and line 463.**

- line 467-468. it says "to reproduce the tsunami correctly..." I am not sure whether your simulations allow to conclude this. I rather say this is in fair agreement, since most of your tsunami waveforms are not well reproduced. If you only compared maximum amplitudes, this analysis whould be included in a discussion section. You can also compare numericaly the simulated and measured maximum amplitudes.

- **We just said "that using a simple fault plane rupture scenario is enough in such case of near field event to reproduce the tsunami correctly with a hazard management point of view ». In the operational context of tsunami hazard management in New Caledonia, and considering the complexity of the coastline bordered by both a fringing reef and a barrier reef, one of the objectives was to test the simple process used to prepare a scenarios database.**

- lines 469-470. Is the paper focused on the validation of MOST and SCHISM models? I am not sure if you can conclude this, due to the fact that arrival time and maximum amplitudes given by your simualtions do not show good agreement. Possible errors (epistemic and aleatory) are many, and you can also discuss about this in a Discussion section.

- lines 473-477. These statements are more suitable for a discussion section.

- **Answer for the 2 last questions/comments: Discussion section available (part 4) between line 427 and line 463.**

- Finally, the conclusions are very weak, since there is no Introduction section with clear

objective and there is no Discussion section either.

- **The introduction will be shortened and clarified with a specific part for the objective and a part for the tectonic context; the available discussion section (line 427 and line 463) will be improved in a further version of the manuscript.**