Natural Hazards
and Earth System
Sciences

Discussions

Interactive comment on "Speeding up and boosting tsunami warning in Chile" *by* Mauricio Fuentes et al.

Mauricio Fuentes et al.

mauricio@dgf.uchile.cl

Dear Reviewer,

Santiago of Chile, April 11, 2019

We have read carefully your review of our article entitled, "Speeding up and boosting tsunami warning in Chile", written by Fuentes M.(1), Arriola, S. (2), Riquelme S. (2), and Delouis B. (3), from (1) Department of Geophysics, University of Chile, Faculty of Physical and Mathematical Sciences, Santiago, Chile, (2) National Seismological Center, University of Chile, Santiago, Chile and (3) Géoazur, Université de Nice Sophia Antipolis, Observatoire de la Côte d'Azur, Nice, France.

We are grateful for the time you spent to review our paper, for all your comments and

useful suggestions to improve the manuscript. In the following paragraphs we present in detail the answer to all questions, comments and suggestions you made.

Best regards, Mauricio Fuentes.

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——— General comments

Reviewer: The paper presents a methodology to speeding up the tsunami forecast in Chile as part of tsunami warning operations. This is a very important topic, in particular because in the last decade many new tsunami warning centers have been established by various countries. This paper presents interesting results for publication. Nevertheless, several issues should be explained, discussed and many data are missing, before accepting the paper. Major revision is necessary.

Response: We provided an annotated version of the manuscript with track of changes (red slanted stands for deleted text and blue for new text.) including all your suggestions.

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Specific comments:

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Reviewer: The results of proposed methods depends mainly on the variation of the source parameters between the different methods used, in particular the slip, the dip and the dimension and location of rupture zone, and the focal depth. One first request : the list and values of parameters of the sources of that paper are missing.

Answer: We added a new table in the supplemental material containing the requested information.

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(2)

Reviewer: It can already been checked on the various maps presented, that the location of the epicenter for the elliptic model, and the location of the center of the rupture zone of the fault model are not the same, and there are not the GCMT location. Why ? How do the authors decide the location of the epicenter, and why the locations are different for the different models ?

Answer: Thank you for noticing this mistake. In the elliptical model, the star stands for Centroid location whereas in the FFM model, the star denotes the epicenter location. We have fixed this in the figures and changed the symbol for the centroid in order to avoid confusion.

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Reviewer: The second question is why did the authors analyzed the results of such method along other coastlines than Chile? It doesn't provide any results about the variability of the warning forecast along the Chilean coastlines. On the other hand, two missing recent events have not been modeled and should be added to the study: Chile 1985 and Antofagasta 1995.

Answer: The main reason is to validate the linear method for the propagation of the tsunami, which needs to be tested in different scenarios. Once we have certain degree of confidence (in statistical terms), we apply it to the particular case of Chile, but not being excluding to be useful in other regions. Also, we decided to pick the last three Chilean tsunamis with associated moment magnitude bigger that 8.0, which also are well recorded and documented.

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Reviewer: One of the recent papers that describes the effectiveness and rapidity of the W-Phase to get robust centroid moment tensor solutions is by J. Roch at al. (Roch, J., Duperray, P. and Schindelé F. (2016) Very fast characterization of focal mechanism parameters through W-Phase Centroid inversion in the context of tsunami warning, Pure Appl. Geophys. 173 (2016), 3881–3893, DOI 10.1007/s00024-016-1258-3). In that paper, the authors analyzed W-Phase results at global and regional scale with specific Green's functions to provide accurate solution in 15 minutes (10 minutes of signal). Due to the characteristics of the very long period W-Phase, it wouldn't be physically feasible to compute sooner W-Phase waves. But it is well known that the first tsunami wave could impact the Chilean coastlines in less than 15 minutes. The mandate and goal of the National tsunami warning center that is facing near-field tsunami warning is to provide the first warning message in less than 15 minutes after the quake occurrence. As the results of W-Phase would not be available, the authors should explain how they would proceed to provide this first bulletin. The authors should identify a preliminary solution to perform modeling before getting the results of the W-Phase computation and getting results in 15 minutes after the quake.

Answer:

In Zhao et. al. 2017 and Riquelme et.al 2018, the possibility to have a W-phase CMT in 6 minutes is studied with good results. Thus, the fact of computing a W-phase solution in a very short time after earthquake location is well reported. We provide you the doi of both papers.

Zhao et al: https://doi.org/10.1002/2017JB014950 Riquelme et al: https://doi.org/10.1785/0220180146

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Reviewer: Second point, the authors informed that for their study, they used W-Phase results. How was computed the parameters of all these past events ? In particular, the location of the centroid moment tensor, and on the strike and dip values used for the elliptic method. On this specific method, the authors should present what are the parameters of the seismic sources needed for the elliptic method, and the values of the parameters for all the events processed in this paper.

Answer: The W-phase method provides the full moment tensor. We just retrieved data from the National Seismological Center in Chile. The data can be accessed through IRIS (www.iris.edu) or USGS (https://earthquake.usgs.gov/). For instance, the W-phae solution of the Nicaragua Earthquake (the oldest in our list) is here: https://earthquake.usgs.gov/earthquakes/eventpage/usp0005ddn/moment-tensor

Therefore, all the parameters you mention are given by this method. Also, we have added a table in the supplemental material with the values used for the elliptic models.

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Reviewer: The next issue is how they plan to implement the complementary messages using W-Phase source parameters. Would this second message be useful when a tsunami warning would already be sent ? How ? Would the CPA be ready to analyze and use a second message ? What is the national standard operation procedure concerning that issue ? The sensitivity of the parameters (slip and dip variation, rupture zone location and size, and focal depth) should be one of the goal of such method. It is well known that the uncertainty of the magnitude in the first 10 minutes after the quake is about +-0.2. And the focal depth is also not good constrained. The variation of the

results with used parameters with the uncertainty should be analyzed. Referee1 suggested to compare with the DART buoy measurement. As currently, Chile has 6 DART installed along its coast, it would be very useful to compare the amplitude computed by the various models on these 6 DART stations.

Answer: Despite there is uncertainty in each of the parameters, we don't try to solve that issue in this paper, but to show how a simple linear method can dramatically decrease the computation times keeping a high degree of accuracy, when compared with standard non-linear methods and the potential for early warning purposes. Nevertheless, the things that the reviewer pointed-out are of high interest and deserve a dedicated study. We have addressed those comments in the discussion section as a future work, including about DART buoys. However, several of the DART stations in Chilean coasts were deployed in 2015-2016 not being possible to use all of them in this study. Also the majority of the buoys belongs to the "far-field domain".

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Reviewer: The last comment would be on the practical use of such detailed result for a warning purpose. Disaster management authorities need level of warning along the coastlines of their country or county. Typically, 3 levels of warning are in place, decided by Unesco: 30 cm, 1m, 3 m. Some countries implemented a 4th level (5 or 6 m). The comparison of run-up computation should take into account such operational criteria to assess the accuracy or the discrepancy between two methods. This should be applied to the set of results. Statistics should be done for the 3 or 4 levels of warning, and for a detailed analysis, it should be demonstrated that the proposed method is more conservative or less conservative than the detailed finer source model. The results of the proposed warning method should be discussed in the scope of the consequences of the difference of warning level with the finest warning level obtained with finer source

and finer propagation modeling. Is their method more conservative or less conservative than the finest method?

Answer: Once the method is developed, the final user can decide what geopolitical subdivision is more suitable, as well as the number of warning levels. Both are easily adjustable in the methodology being part of the criteria adopted for the government institutions. It is hard to say which one could be more conservative even with such statistical analysis, because there are other factors, namely psychological, communicational, etc. One should have a good compromise between quantitative results and simplicity on the way the information is transmitted (which can be somehow subjective). Nonetheless, this discussion is highly valuable, and we have included in the manuscript.

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Reviewer: Proposed modifications on figures.

a) Figure 2, the scale of the run-up axis should be the same for both figures left and right

b) Figure 5. The presentation of far field and ocean scale results is useless for the Chilean tsunami warning system and not in the scope of this paper. This figure should be removed.

Answer:

a) Figure 2 is now with same scales.

b) One of the main objectives of this work is to show the power of the linear method, so another simple and fast application, is to compliment any scenario with a global map of travel times, even allowing the inclusion of different effects.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2019-9/nhess-2019-9-AC4-supplement.pdf

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