Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2020-47-AC1, 2020

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Wide sensitive area of small foreshocks" *by* Chieh-Hung Chen et al.

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Received and published: 10 July 2020

The authors of the submitted research analyse with mathematical/statistical tools published seismic event catalogues from areas of high seismicity (Taiwan and Japan) in an attempt to identify patterns in the distribution on time and space of foreshocks of larger events. The presented results point to a distribution much wider of the foreshocks in time (up to 60 days) and space (up to 400 km of the main shock epicentre) of those currently accepted, even for main shocks of moderate magnitude. Such kind of analysis is promising; but I think as performed and presented in the submitted research is not yet ready for publication. To me, it looks like the pieces of the submitted paper have been assembled in a hurry. The used methodologies need more explanation (why and how they are applied). Even more comments on the choice of the data are also needed. Moreover, a revision of the English syntax is needed. The sense of phrases is difficult to follow in many cases.

For these reasons I think the submitted research needs a deep and throughout revision before it can be accepted for publication. In the following paragraphs I point some specific questions to be addressed on the submitted text.

-Methodology- Line 85. Citation Chen (2014) is not in the reference list.

Reply:

The correct reference is Chang (2014) and has been cited in the manuscript. (Line 96)

Lines 87-89. It is necessary to introduce a minimum description on how ZMAP software removes aftershocks.

Reply:

" The ZMAP software package for MATLAB (Weimer, 2001) was utilized to remove and/or omit influence from duplicate events, such as aftershocks." has been rewriten as "To distinguish dependencies from independent seismicity, the earthquake catalogs are declustered. Therefore, the ZMAP software package for MATLAB (Weimer, 2001) was utilized to remove and/or omit influence from duplicate events, such as aftershocks. The declustering algorithm used in ZMAP is based on the algorithm developed by Reasenberg (Reasenberg, 1985)." (Lines 98-102)

Lines 89-95. Idem: a minimum description on how clusters are classified and the meaning of the input parameters is necessary.

Reply:

" We classify clusters by using the standard input parameters (proposed in Reasenberg, 1985 and Uhrhammer, 1986) for declustering algorithm. The minimum and maximum values of the look-ahead time for building clusters are 1 and 10, respectively. The probability of detecting the next clustered event used to compute the look-ahead time is 0.95. The effective minimum magnitude cut-off for catalog is given by 1.5 and the xk factor for the increase of the minimum cut-off magnitude during clusters is given by

0.5." has been rewriten as "We classify clusters by using the standard input parameters (proposed in Reasenberg, 1985 and Uhrhammer, 1986) for the declustering algorithm. Because the aftershock clusters in a small area and in a short period of time do not conform to the Poisson distribution, which requires removing the aftershocks from the earthquake sequence. Therefore, some parameters can be set as follow: The look-ahead time for un-clustered events is in one day, and the maximum look-ahead time for clustered events is in 10 days. The measure of probability to detect the next event in the earthquake sequence is 0.95. The effective minimum magnitude cut-off for the catalog is given by 1.5, and the interaction radius of dependent events is given by 10 km (van Stiphout et al., 2012)." (Lines 103-111)

Line 95. "The 10 of crack radii: : :" Do you mean 10 times the crack radii? Please, make clear this phrase.

Reply:

Sorry for the ambiguous statement, the sentence is indicated as the interaction radius of dependent events is given by 10 km. The modified description is listed at lines 110-111.

Line 96. Cite Stiphout (2012) is missing in the reference list.

Reply:

The reference has been added in the list.

van Stiphout, T., J. Zhuang, and D. Marsan (2012), Seismicity declustering, Community Online Resource for Statistical Seismicity Analysis, doi:10.5078/corssa52382934. Available at http://www.corssa.org.

Lines 99-102. If I understand properly "crack" and "break" events are definitions you introduced in your analysis, being "crack events" quite equivalent to foreshocks and aftershocks. Please, make clear all these terms.

Reply:

Sorry for the confusion. The "crack" and "break" events have been defined in the manuscript in lines 114-125. Note that we assumed the break event is an earthquake. The crack events can be foreshocks and aftershocks. We stack the crack events to the break events by the time and spatial distance to examine their relationship.

Lines 102-104. There is some problem with the minimum completeness magnitude of the catalogues. Looking at figures S1-S4 it looks like the events in the Taiwan catalogue are included in the Japanese catalogue. Something should be said about this fact. Moreover, the Japanese catalogue comprises many events far away from the main islands (23-34N, 138-147E). I think this whole region does not have the dense seismometer network claimed in lines 83-85. All these points should be clarified in the text.

Reply:

Thank you for your comments. We have modified the results of the Japan catalogs by using the earthquakes that occurred in the northern side of the latitude of 32°N to mainly concentrate in areas with the dense seismometer network and to avoid the double counts of earthquakes in the Taiwan catalogs (lines 187-191). This result is consistent with the previous results, but in order to avoid the problems raised by the reviewer, the revised version will be based on this result. (also see Figs. 1 and 2 in the revision)

Lines 109-110. I assume the spatial and temporal resolutions of the grid are a choice of the authors. If so you may comment if you try other resolutions and/or the reasons for your choice.

Reply:

Sorry for the confusion. The statements have been revised as "Note that the spatial and temporal resolutions of the grids of the spatiotemporal distribution are 10 km and 1 day, respectively, based on the declustering parameters in the ZMAP software." (lines 130-132). Note that the statements associated with the declustering parameters also used in the ZMAP software and the declustering process in ven Stiphout et al., (2012) and Zare et al., (2014). (Lines 107-111)

Reference

Zare, M., Amini, H. and Yazdi, P.; Recent developments of the Middle East catalog, J. Seismol., 18, 749–772, 2014. https://doi.org/10.1007/s10950-014-9444-1.

Lines 113-116. The superimposition process statistical tool should be described. It is not a common tool in seismicity studies.

Reply:

The associated statements have been revised and added for clarification. In practice, the superimposition is a process to stack numerous datasets that can migrate unique features for a few datasets and enhance common characteristics for the most datasets. The count in each grid of the spatiotemporal distributions for all the break quakes are superimposed as a total one based on the occurrence time and epicentral distance of the break quakes. (Lines 138-143)

Lines 118-121. It is not clear to me what "migrate rare characteristics" means. Please clarify this phrase.

Reply:

The associated statements have been revised as "In practice, the superimposition is a process to stack numerous datasets that can migrate unique features for a few datasets and enhance common characteristics for the most datasets.". (Lines 138-140)

-Analytical Results- Lines 130-132. All M2 events are foreshocks or aftershock of M3 events? Cannot they be independent events?

Reply:

This is a very interesting comment. Initially, the opinion from the authors are the same with the reviewer. M2 events can be foreshocks or aftershock of M3 events. Meanwhile, the authors understood that the ZMAP may not fully remove the influence from M2 aftershocks. In fact, we analyze the data without any assumption except for taking the break event as an earthquake. Here, we made the artificial events as the break events for the tests based on that the relationships between the artificial and break events are (1) independent in the time and spatial domain; (2) time dependent (i.e., the same occurrence time but distinct location); (3) location dependent (i.e., the same occurrence location but distinct time). These results are processed by using the same method to construct the spatiotemporal seismic density distributions and the spatiotemporal normalized variations in Figs. A and B (in below) for comparison. No significant increase of the seismic activity can be observed in Figs. 1b-d and 2b-d for the artificial events. In contrast, we can find increase of the seismic activity in Figs. 1a and 2a. This suggests that M2 events could related to the M3 events with a variable distance along the time. (Lines 161-175).

Lines 132-134. What does it means that S/N ratio increases 135 times? Please clarify.

Reply:

The associated statement has been removed.

Another issue: 17993 M3 events in the period 1991-2017/6 mean 2 events per day roughly. As Taiwan is 400 km long approx., it means that in a period of 60 days and 400 km as you are using in your analysis. there are many M3 earthquakes (100 approx.). It is not clear to me how the M2 events are associated with the M3 events. Maybe a good description of the superimposition process as applied in this case clarifies this issue.

Reply:

Thank you for your comments. Those M3 events do not occur in the same region. Instead, the M3 events widely distributed in Taiwan and Japan areas. The distances between the M2 and M3 events are utilized as an important parameter in this study. The distances from the M2 to the distinct M3 events are different. This suggests if the relationship does not exist that can be mitigated through the stacking processes due to the distinct spatial distribution dominated by the diffident distances (also see Figs. A and B). In contrast, if the relationship dose exist, it can become obvious after the stacking of more than 10 thousand of the M3-4 events. The authors have rewritten the statements associated with the superimposition process in lines 138-143.

Lines 145-164. The previous pointed issues make difficult to follow the discussion on the results.

Reply:

Sorry for the confusion. In this paragraph, the authors focus on the areas with the increase of seismicity density before earthquakes that extends from the fault rupture zone to an external place. The associated statements have been written in the manuscript (Lines 175-212).

-Discussion- In fact this section presents a different analysis, using seismograms and the PCA method. Certainly, the presented analysis has been inspired by the results obtained in the previous section; but it can be performed and presented in a totally independent form. Thus, it should be better presented as another section of analysis results. It is not clear how you are using the PCA analysis in this case. Some figure showing an example of the procedure described on lines 217-222 can help.

Reply:

The statements associated with the descriptions and results associated with the PCA have been move to the new section of the principal component analysis (PCA) on the continuous seismic waveform in lines 234-248. Figure 3 has been added to reveal the energy of the principal components and the first principal component retrieved from continuous seismic waveforms at 31 stations. Figure S5 have been moved to the main

text as Figure 4. Note that Figure 4a shows that the amplitude ratio associated with the Meinong earthquake without the superimposition or the stacking process. For the superimposition or the stacking results associated with the M4-5 and M3-4 earthquakes are shown in Figs. 4b and 4c.

Lines 237-246. There are a lot of suppositions on the used dimensions. If horizontal dimensions (100 x 100 km2) can be roughly deduced/assumed from the previous results (obtained in this section and the previous one), the thickness between 500-1000 m needs a good explanation.

Reply:

The authors appreciate that the reviewer can accept the area in the horizontal dimensions. If the resonance model in the manuscript is true, the unknown parameter of the stress plate is the thickness. The area in the horizontal dimensions is given by the observation in this study. The resonance frequency is obtained by the results of continuous seismic waveforms. The thickness between 500-1000 m is obtained based on the resonance model. The authors just propose a potential model to connect the wide area of increase of seismic activity and the frequency characteristics of crustal vibrations. The authors do not have any evidence to support the thickness between 500-1000 m. In fact, the thickness of the seismogeneric areas is smaller than it of the crust that can be one of the candidates of potential causal mechanism. The authors understood that the debate of the resonance model cannot be solved immediately. We have shortened the statements associated with the resonance model. The original Fig. 4 has been moved to the supplementary for references.

Lines 275-276. I cannot see the need for this citation here. Even more, I has been unable to find the value 2700 km/mˆ3 in the cited paper or on the additional information.

Reply:

The reference has been removed from the manuscript.

Figure Caption

Fig. A. Spatiotemporal seismic density distributions in Taiwan. (a) is computed by the M2 events relate to the real M3-4 events. (b) is computed by the M2 events related to the random M3-4 events in the time and frequency domain. (c) is computed by the M2 events related to time dependent M3-4 events. (d) is computed by the M2 events related to location dependent M3-4 events.

Fig. B. Changes of spatiotemporal normalized variations in Taiwan. (a) is computed by the M2 events relate to the real M3-4 events. (b) is computed by the M2 events related to the random M3-4 events in the time and frequency domain. (c) is computed by the M2 events related to time dependent M3-4 events. (d) is computed by the M2 events related to location dependent M3-4 events.

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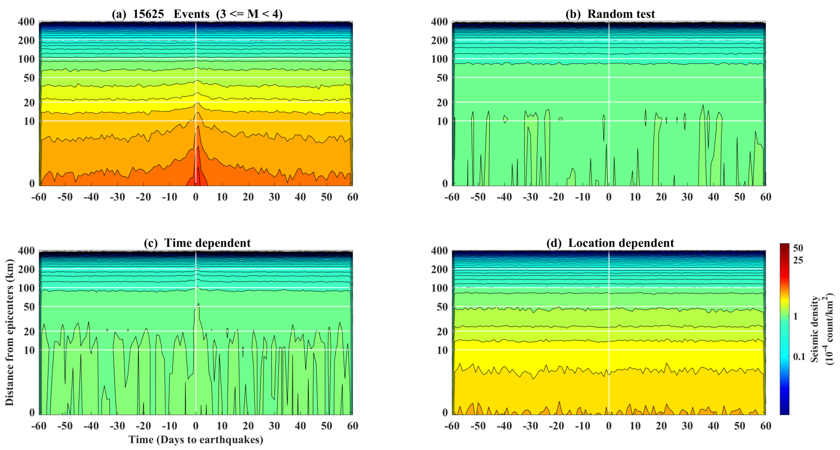

Fig. 1. Fig. A. Spatiotemporal seismic density distributions in Taiwan.

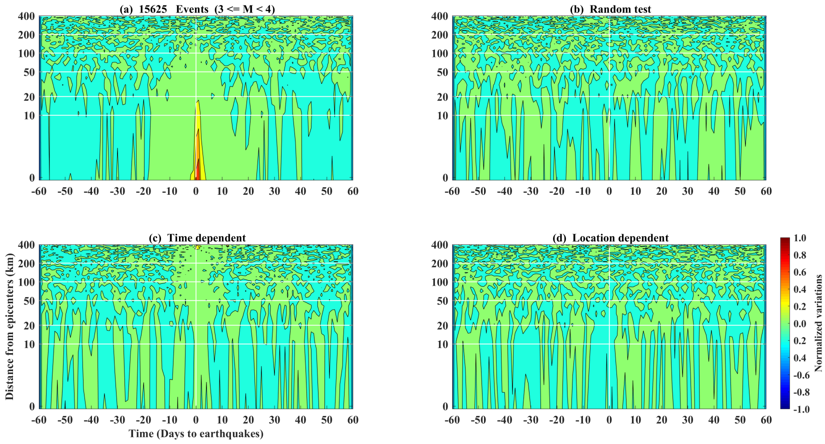

Fig. 2. Fig. B. Changes of spatiotemporal normalized variations in Taiwan