Response to the comments of Reviewer 1

The authors would like to thank the reviewers for their constructive and positive reviews of our manuscript. We would like to highlight several essential points that all three reviewers commonly ask:

First, our paper is a manuscript that proposes a new approach integrating the multivariate Bernoulli earthquake occurrence model and stochastic source modelling. As such, a natural scope/application of the new method is the time-dependent Probabilistic Tsunami Hazard Analysis (PTHA). We do not take a strong position as to which time-independent and time-dependent models are appropriate. However, we have noticed that the wordings in our original manuscript in supporting the time-dependent model for PTHA were relatively strong, and hence, once we are invited to revise the manuscript, we will soften our statements and clarify the motivation of the paper.

Second, the justification for the choice of the time-dependent PTHA model was not well presented in the submitted manuscript. We have prepared additional texts both in the introduction and the results and discussion sections (see details comments below) to highlight some more recent studies (i.e. Williams et al., 2019; Griffin et al., 2020; Moernaut 2020). Those studies suggest that the global paleoearthquake records provided empirical support for weakly quasiperiodic earthquake recurrence. Therefore, it can be used to justify the use of renewal models (i.e. Brownian Passage Time (BPT) model) for seismic/tsunami hazard assessment.

Third, this manuscript presents a new alternative to carrying out a time-dependent PTHA as a kind of sensitivity analysis using Indonesia (Sunda) applications. As such, we should recognize the limitations and challenges to be resolved. In our submitted manuscript, we did not provide the limitations of our study highlighted by the three reviewers. These include the 1D approach in earthquake rupture modelling, BPT parameter estimation using the Bayesian approach, and space-time earthquake rupture modelling. Subsequently, we will dedicate a new section explaining our limitations in the revised manuscript.

Fourth, a combination of multiple earthquake occurrence models can be included as a logic-tree approach. However, we did not explore this in this study as it is out of the scope. We stay on our objective: presenting a new method that combines multivariate Bernoulli and stochastic source modelling methods, which we hope to promote many applications in future.

Fifth, the valuable suggestion from the reviewers to re-do the analysis, specifically in the earthquake rupture modelling and Bayesian parameter estimation, is essential. We will re-do the earthquake rupture modelling and Bayesian parameter estimation and include the updated results in the revised manuscript:

For the earthquake rupture modelling:

- The instrumental events (i.e. the 2007a, 2007b and the 2010 events) will be excluded in modelling the time-dependent earthquake rupture.
- The earthquake catalogue data to develop a magnitude-frequency model for the time-independent approach will include the paleogeodetic records provided in Philibosian et al. (2017) by excluding the instrumental events (i.e. the 2007a, 2007b and the 2010 events). Therefore, both the time-dependent and time-independent approaches use similar earthquake data. An updated frequency-magnitude model will then be developed for the time-independent approach by fitting the Gutenberg-Richter (GR) relationship using Weichert (1980) method to treat the varying completeness magnitude. Moreover, the number of low-magnitude scenarios (i.e. < M 7.625) will be reduced by considering only the magnitude of ≥ M 6.0 (in the submitted manuscript, we use the magnitude of ≥ M 5.0).

For BPT parameters estimation using the Bayesian approach:

- The prior setup needs to be updated and adopt the uninformative priors, e.g. as used by Fitzenz et al. (2010).
- The BPT parameters estimation using the Bayesian approach will be further improved to use both the maximum a posteriori (MAP) and full posterior parametric uncertainty in defining the final BPT parameters to consider the uncertainty in BPT parameter estimation.

Furthermore, to respond to the reviewer's comments, we have copied the reviewer's comments and in italicized text.

General Comments

(1) The study is based on the idea that a BPT or other time dependent rupture model more accurately represents earthquake behavior along the Sunda subduction zone. Given numerous papers refuting the seismic gap hypothesis for subduction zones in general (e.g., Rong et al., 2002 who cite Matthews, 2002), it seems that a logical first step for any study region is to falsify a Poisson null hypothesis.

Thank you very much for these valuable comments. We are aware that we did not include a clear explanation regarding the selection of the time-dependent approach (i.e. BPT model) in the earthquake rupture modelling. Subsequently, we will add the following texts (in the introduction) once we are invited to revise the manuscript:

In general, the earthquake rupture can be modelled using two approaches: Poisson and non-Poisson. The Poisson approach employs a memory-less Poisson process for long-term hazard assessment and is commonly adopted for earthquake rupture modelling (e.g. Burroughs and Tebbens, 2005; Tinti et al., 2005; Orfanogiannaki and Papadopoulos, 2007). However, assuming a lack *of memory between major earthquake occurrences is often viewed as a first approximation, inconsistent with the physics of elastic rebound (Reid, 1911; Anagnos and Kiremidjian, 1984; Berryman et al., 2012). As a result, many studies adopted a renewal model of earthquake occurrence, i.e. non-Poisson model (Matthews et al., 2002; Zhuang et al., 2012; Field et al., 2014; Williams et al., 2019; Griffin et al., 2020) to carry out a time-dependent earthquake rupture modelling. More recent studies using global paleoearthquake records (i.e. Williams et al., 2019; Griffin et al., 2020; Moernaut 2020) showed that large earthquakes in the subduction zones recur more regularly than expected from exponentially distributed interevent times (i.e., a Poisson process). Specifically, the earthquake recurrence in the Mentawai Sunda subduction zone is categorized as more like a supercycle type (i.e. a combination of large gaps and clusters), demonstrating that successive large earthquakes are dependent on each other (Salditch et al. 2020). Therefore, this study adopts the renewal model (i.e. BPT distribution) for earthquake rupture modelling in the Mentawai segment of the Sunda subduction zone.*

(2) Although the definition of fault segments is based on 450 years of earthquake occurrence, there still might not be sufficient to determine if these segment boundaries are persistent (cf., Jackson et al, 2011).

Thank you very much for this comment.

We are aware that the current fault segment in our study may not have persistent boundaries and can be further extended. For instance, the segment can be extended to about 900 km, starting from North of Batu Island to South of Enggano Island (Natawidjaja et al., 2006; Muhari et al., 2011; Muhammad et al., 2016). Our previous studies have implemented such a model (Muhammad et al., 2016, 2017, 2018). However, in this study, to integrate the Spatio-temporal earthquake rupture modelling and stochastic tsunami simulation, we need to consider the past rupture areas to model future ruptures. Such rupture areas are developed based on the coral microatoll samples from 21 sites along 600 km of the Mentawai Islands (Natawidjaja et al., 2006; Shieh et al., 2008; Philibosian et al., 2014, 2017). Southern parts of Mentawai are not included in our model, although they could be a part of rupture areas because these areas lack of coral samples. However, this 600-km segment with a total area of 150,000 km^2, i.e. 600 km (length) × 250 km (width) is still consistent with the scaling relationships (e.g. Goda et al. (2016) and Thingbaijam et al. (2017)). Figure R1-1 presents the relationship between the fault areas and magnitude based on the Goda et al. (2016) and Thingbaijam et al. (2017) scaling relationships. The figure shows that the maximum fault areas used in this study represent the magnitude of between M 9.0-9.2. Therefore, it can still be adopted to constrain the boundaries of finite fault models developed in this work.

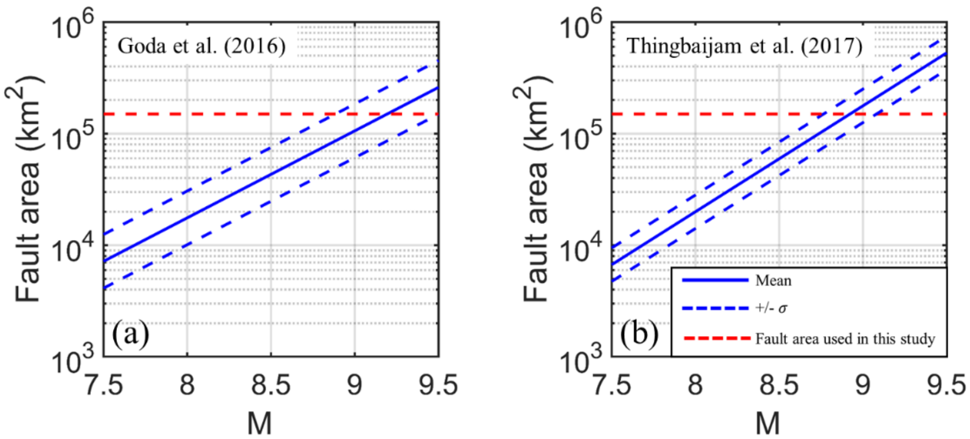

Figure R1-1. Fault areas and moment magnitude (M) relationships based on the Goda et al. (2016) and Thingbaijam et al. (2017) relationships.

(3) The earthquake occurrence model is based on a 1D (along strike) representation of the subduction zone. For the Sunda subduction zone, as with other subduction zones with a broad shelf, however, tsunami generation is critically dependent on the dip extent of rupture as was notably observed in comparisons of the 2004 and 2005 earthquakes (e.g., Geist et al., 2006). The limitation of the 1D approach should be mentioned.

Thank you very much for your valuable comment.

The 2D segmentation can also be possibly represented by our current setup. The first direction is along strike segmentation whereas the asperity region can be regarded as a along width segmentation as large concentration of slips is allowed in this area. This was initially considered to accommodate notable observations from the recent tsunami events, including 2011 Tohoku – large concentration of slips along the trench line. In reality, this may capture various geological environments – such as outer wedge rupture. However, such an explanation has not been included in the submitted manuscript and we will include this in the revised manuscript once we are invited to revise it.

On the other hand, In our setup, the strike and dip angles of the fault-plane of tsunamigenic source models are typically 296^o to 326^o and 7^o to 19^o, respectively. These values are comparable to the slab models for the Sunda subduction zone produced by the USGS (Hayes et al., 2009, 2012). The top edge of the fault plane is located at a depth of 3 km. This depth is consistent with the past Mentawai finite-fault models developed for the 2010 Mentawai tsunamigenic earthquakes and the twin events of the 1797 and 1833, which have the top edge depth between 2 km and 5 km (Newman et al., 2011; Satake et al., 2013; Philibosian et al., 2014; Yue et al., 2014).

We have not explained this clearly in the manuscript, and we will include it in the manuscript once we are invited to revise the manuscript.

(4) It seems that it would be straightforward to estimate uncertainties in mu, alpha, and gamma from the posterior distributions (confidence intervals). These uncertainties could then be used as part of the probabilistic calculations.

Thank you very much for this constructive comment.

We understand that the BPT parameters estimation using the Bayesian approach will be further improved to consider both the maximum a posteriori (MAP) and full posterior parametric uncertainty. Therefore, we wll include this approach in the following revised manuscripts once we are invited to revise the manuscript.

(5) My impression is that the maximum magnitude earthquake considered is from the 450-year record and essentially is an event that spans segments 1-6. Even though the tsunami from an Mmax event would have a low probability, such an event may pose a more significant component of the aggregate hazard for longer exposure times than considered in this study. It should be clarified how Mmax is determined and whether a penultimate event could extend beyond the study region.

Thank you very much for this valuable comments.

The maximum magnitude scenario was selected based on geodetic, paleo-geodetic, and paleo-tsunami studies (Zachariasen et al., 1999; Natawidjaja et al., 2006; Sieh et al., 2008). Those studies indicated that the accumulated slip in the Mentawai segment of the Sunda subduction zone might generate tsunamigenic earthquakes ranging from M 8.8 to M 9.1. Specifically, coral microatoll samples from 21 sites along 600 km of the Mentawai region were used to constrain the dates, spatial extents and approximate earthquake source models for tsunami generation (Natawidjaja et al., 2006; Shieh et al., 2008; Philibosian et al., 2014, 2017). In our study, the tsunami simulation can not be extended into more than six segments (600 km) due to the availability of the coral microatoll samples beyond these six segments. However, this 600-km segment with a total area of 150,000 km^2, i.e. 600 km (length) × 250 km (width) is still consistent with the scaling relationships (e.g. Goda et al. (2016) and Thingbaijam et al. (2017)). Figure R1-2 presents the relationship between the fault areas and magnitude based on the Goda et al. (2016) and Thingbaijam et al. (2017) scaling relationships. The figure shows that the maximum fault areas used in this study represent the maximum magnitude of between M 9.0-9.2. Moreover, we allow the model to have a maximum magnitude up to about M 9.1 (+/- M 0.1 of M 9.0) in developing the stochastic earthquake source model, and hence, such a number is still sufficient to represent the maximum *magnitude event that may occur in the Mentawai segment of the Sunda subduction zone. Therefore, it can still be adopted to constrain the boundaries of finite fault models developed in this work.*

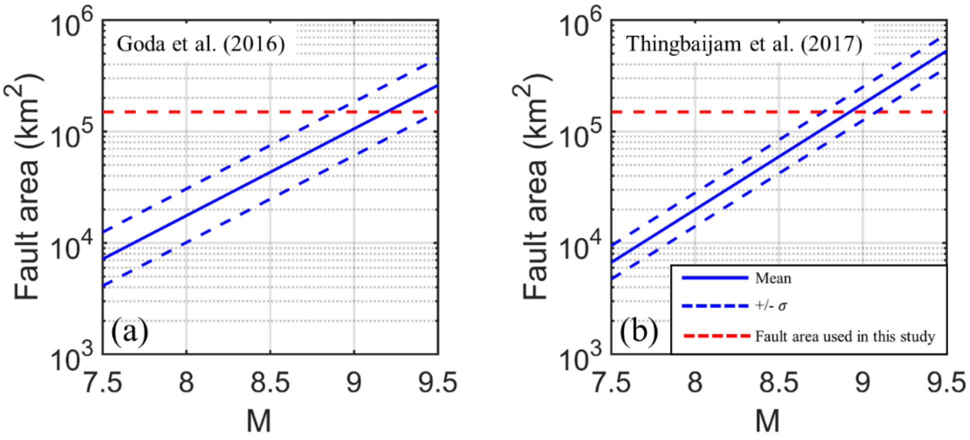

Figure R1-2. Fault areas and M relationships based on the Goda et al. (2016) and Thingbaijam et al. (2017) relationships.

More importantly, we are aware that this is one of the limitations of our current work. Therefore, we will emphasize this issue in the following revised manuscript once we are invited to revise it.

(6) Tsunami heights seem to "saturate" at nearly 10 m (Figure 13). Is this dependent on the largest magnitude earthquake or is this caused by a hydrodynamic effect?

It is mainly due to the hydrodynamic effect. At other coastal points, the tsunami height may exceed 10 m. To confirm this, we plot tsunami heights along the coast of western Sumatra from all 21 scenarios, as shown in Figure R1-3. The figure shows that the tsunami height can be more than 10 m.

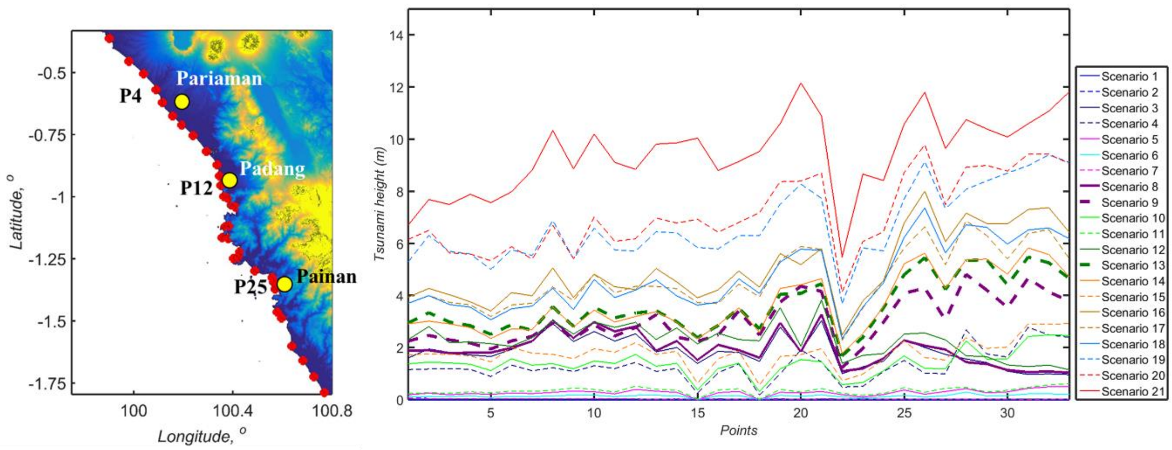

Figure R1-3. Tsunami height along the coast of Western Sumatra from the 21 scenarios adopted in this study.

In-line comments

To respond to the reviewer's in-line comments, we have copied the reviewer's comments and then replied in italicized text.

L42: Vere-Jones' stress release model (cf., Bebbington and Harte, 2001) could also be mentioned—more relevant to this study. Moreover, Eqn. 3 is a cumulative distribution function, not a frequency-magnitude distribution.

> *We will make the change based on your comments in the revised manuscript.*

L141: I couldn't find in the manuscript where the specific magnitude-area relation used was mentioned. Since this is often a contentious choice, especially for subduction zone earthquakes, the specific relation and its justification should be indicated.

> *In the stochastic source model generation, we only consider the length and width generated based on the scaling relationships developed by Goda et al. (2016). However, we used magnitude-area relation to constrain the generated parameters in the final checking of the generated parameters. We have confirmed that the generated area of the finite-fault model is consistent with the adopted scaling relationships.*
>
> *We will add this explanation once we are invited to revise the manuscript.*

L257: How is distance D determined?

> *A length of 100 km corresponds to a minimum magnitude (M 7.75) of a significant tsunami-earthquake adopted in this study. Such a value is consistent with the length of fault developed by Goda et al. (2016) that is used to generate the stochastic earthquake source modelling.*

L316: Same variable D used for slip here and distance in L257.

Fig. 3: "occurred scenarios" is awkward. Could just say "scenarios".

> *We will change these terms in L316 and Fig. 3 in the revised manuscript.*

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