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Discussions

Interactive comment on "Discrete element modeling of a subduction zone with a seafloor irregularity and its impact on the seismic cycle" *by* Liqing Jiao et al.

Liqing Jiao et al.

chchan@ncu.edu.tw

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"This paper presents the DEM simulation of the subduction process with an indenter on the subducting plate. The sequence of thrusting events and associated pre- and post-processes are examined as the source of the periodic earthquake system. The numerical simulation successfully reproduces the splay and backstop thrust formation with large- and small-scale slip events which are consistent with seismic observations. The analysis of deformations in the different locations and timings are presented. From the results, the author pointed out the significant role of sea surface roughness in the seismic cycle."

Many thanks to the Reviewer 1's comments. From these comments, we could see that he/she is interested in the numerical simulation of thrusting events and the splay and backstop thrust formation, which are main key points in the paper. He/She understood well about the scientific issue we documented there and main purpose of our paper. We appreciate him/her reviewed our paper.

"The impact of seafloor irregularity on the seismic cycle is still not well understood. Therefore, this type of numerical study should be interesting for geodynamics, geology, and seismic researchers, because it is difficult to access the plate boundary by the direct observation."
I agree with the importance of seafloor irregularity on the seismic cycle. There are lots of publications related to the influence of the seafloor irregularities, such as about the seismic behavior with irregularities (e.g., Lay and Kanamori, 1981; Lay et al., 1982; Watts et al., 2010, geological observation of the faulting in the above wedge (e.g., Bilek, 2007; Bilek et al., 2003; Wang and Bilek, 2011, 2014; Wang and Hu, 2006) and numerical simulation of faulting at the subduction zone with irregularities (e.g., Ruh et al., 2016). In the revised manuscript, we included a simulation model without seamount, shown in Section 2.2.4. In this model, the slip velocity along the slab is temporally homogeneous without any significant slip asperity (Supplementary Fig. S2). This model cannot explain the megathrust events in a subduction zone, confirming the importance of seafloor irregularity.

"However, the current manuscript lacks the presentation and supporting data for the novelty needed for Research articles. I agree that the author successfully reproduces the characteristic feature of repeating earthquakes events. It is, however, difficult to find the new findings from this DEM simulations."
In our work, we used the Discrete Element Method (DEM) to simulate the repetitive

megathrust behavior and faulting inside the accretionary wedge, since only the DEM could allow us to simulate the earthquake cycle and generation and propagation of the splay faults inside the above continental wedge. Using this method to simulate the earthquake cycle is definitely new and is helpful for solving some questions not easily to be answered through other numerical/geophysical approaches. We have elaborate the advantage of this method in Introduction. Some researchers used the finite element method (FEM) to simulate the one earthquake cycle and some used DEM to focus on the fault distributions in the above plate. But so far, the DEM hasn't been implemented to simulate the earthquake cycles, due to technique limitation. Here, in our model, we consider the healing function, which could allow us to simulate the earthquake cycle in DEM. Our models first confirms the importance seafloor irregularity on the generation of megathrust events. We then concludes our models fit observations, including paleseismic record, spatial patterns of seismicity in a subduction system (such as seismicity along megathrust, splay fault, and back prism zone). Our model also explains seismogenic domains along the megathrust identified from the seismic observations by Lay et al. (2012). In addition to confirming the feasibility of this model by comparing with observations. In addition, the outcomes of this model (e.g., earthquake cycle with uncertainty, triggering interaction between megathrust and splay fault) could also contribute crucial parameters for subsequent probabilistic seismic or tsunami hazard assessments for a subduction zone system.

"The indication of a significant role of sea surface roughness to the seismic cycle is not new."
As we interpret, the scientific issue has existed for long time. I do agree that the significant role of the seafloor surface roughness is not new. But, using DEM to reproduce the earthquake cycle in the Sumatran subduction zone with the seamount is novel.

"For example, what are the key parameters, dynamics, and geometry for the successful fit to the time interval length scale, thrust angle of the observation¿'
I do agree that the listed parameters do affect the earthquake cycle, either in the nature or in the numerical modeling. It is also very good if we could test key parameters, geometry of the slab to fit the interval length scale or thrust angle here. But our purpose in this paper is not to test the parameters. Alternatively, we simplify the model based on the seismic observations and proposed a model with a fixed geometry for subducting slab, based on the observations from a deep seismic reflection survey (Singh et al., 2011). Our purpose here is to simulate the earthquake cycle in the subduction zone based on the geometry of the interpretation from observations. The researchers observed the extreme obvious irregularity along the subducting slab, which is a high seamount in this zone. As the previous works showed, the obvious roughness, such as seamount, is the main controlling effect on the faulting and seismic behavior in the subduction zone.

"How robust your simulation result is?"
Our simulation is simple that considered the geometry effect along the interface. Because the implemented geometry includes a seamount, which is based on the seismic profile (Singh et al., 2011). In the revised manuscript, we add the results of the slab without seamount in the supplementary materials. We could see that such geometry did affect significantly either on the seismic cycle or the faulting behavior inside the overriding plate. I could see that this irregular geometry along the slab do control the seismic behavior and the overriding deformation in the Sumatran subduction zone.

"What are the new mechanisms not found in earlier studies?"

We simulate the earthquake cycle in the Sumatran subduction zone and the faulting in the above plate. There is no previous study implementing the DEM on the earthquake cycle in the Sumatran subduction zone before. In our modeling, we summarize the earthquake cycle and corresponding deviation along the megathrust fault and also the relationship with the splay faulting inside the overriding plate. Such outcomes could be crucial for subsequent probabilistic seismic or tsunami hazard assessments for a subduction zone system.

"Without such quantitative constraints or significant findings from numerical simulation, this simulation result is just the ad-hoc result to reproduce realistic-like event."
The quantitative analysis is very important. We do analyze the period of the seismic cycle, the displacement of the wedge and on the surface as well. As we interpreted, in the Mentawai zone, the seamount should dominate the roughness of the surface of the subducting slab. To simulate the earthquake cycle along the interface, we only consider this main roughness here. Thus, we do not agree with the reviewer for the interpretation here "without such quantitative constraints or significant findings".

"I suggest more simulation runs with different parameter sets for these findings and then we can get more understanding of the role of seafloor irregularity on the seismic cycle. You might already perform such simulation studies, but it was difficult to know in the present manuscript."
The different size of the seamount could affect the seismic cycle, and different roughness or other geological features (such as basins) on the slab could also affect on the seismic cycle as well, if without the big seamount. But, this beyond the scope of this study. Alternatively, we add the test without seamount in the supplementary material to complete the discussion in the main text.

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