Review of the manuscript of Kutschera et al., “Linked and fully-coupled 3D earthquake dynamic rupture and tsunami modeling for the Húsavík-Flatey Fault Zone in North Iceland”

Summary

Kutschera et al. investigate the tsunamigenic potential partially offshore transform fault in North Iceland by and presenting six dynamic rupture model scenarios based on two fault geometries (simple/complex) and three rupture nucleation points (west/center/east). The physics-based models are constraint by empirical friction laws, pre-stress conditions and fault strengths. The rupture simulations are once one-way linked to the tsunami models, once fully-coupled with them.

The authors find that simpler fault geometries cause significantly larger ruptures, higher displacement and higher tsunami waves. They show that the fully-coupled model scenarios create more detailed wave propagation fields that also include seismic and acoustic waves. Since the latter are very fast, they could potentially be implemented in early warning systems, the authors conclude.

The manuscript presents state-of-the-art tsunami-modeling that provides realistic upper estimates of tsunami heights for nearby coastal towns, a relevant information for the North Icelandic municipalities. The text clearly reflects that the author are experienced experts in dynamic rupture modeling and the tectonic context. The model set up seems robust to me, thus my main comments (see below) mostly address the discussion and interpretation of the model results. I also suggest a few modifications of text and figures to improve the overall reading experience, particularly for modeling laypersons. I hope the authors will find them useful.

Main comments

Large slip caused by simple fault geometry

A) You state that the fault accommodates 6-9 mm/yr of slip since the last earthquake ~150 years ago in 1872. The estimated slip deficit would be approximately ~1 m today. This stands in large contrast to your observed coseismic slip of up to 8 m, making me doubting your pre-event model conditions. Can you explain the reason for this large value (e.g. overshooting, low friction parameters, etc.)? Is such high slip even realistic on a 100 km long fault? Could you somehow dampen this slip using other pre-event model conditions?

B) I am impressed by how the complex fault geometry hinders large earthquakes. Given that the *real* fault geometry is even more complex, I would expect that M7 earthquakes are not even possible, but of course they are! Can you explain this apparent contradiction further? Or is it irrelevant, because the predicted wave heights far from the source are of a similar size (factor ~2)?

Vertical coseismic displacement Your models predict near-surface, vertical coseismic displacements at the rupture end, which is what is also often observed strike-slip earthquakes (cf. Interferograms and geodetic slip models of Ridegcrest, Maduo, Muji, Sarez). It might be not the main scope of this earthquake, but I find this interesting enough to briefly be discussed: Why to the

segments rotate? Is it consistent, does always the same side of a right-lateral fault exhibits up motion, or what does it depend on (nucleation, dip etc.)?

Figures Revise the number of figures to improve the ratio between visual presentation and text description. For example, Figure 10-12 and B3-B4 use a lot of space, but are hardly discussed. Maybe there is a better way to present (parts of) them and make your point? Figure 13 uses a full page, only to state that coupled models provide more details.
For a better recognition, please use the same symbols in all figures, e.g. mark the nucleation point in all relevant figures similarly. To better follow your argumentation, please refer more often to the figure under discussion, maybe also mark features under discussion with (more) arrows and labels.

Adjective-chains Some sentences contain extremely long chains of adjectives, making the sentence difficult to read, particularly, when not an expert in the domain. Some verbs, “of”s, or commas might help to improve the readability. Examples are “both one-way linked 3D earthquake dynamic rupture and shallow-water equations tsunami simulations” (L70), “time-dependent one-way linked and 3D fully-coupled earthquake-tsunami modeling” (L6), “recently developed physics-based dynamic rupture models” (L73), L79/80, L94/95, “the dynamic rupture initial conditions” (L100), “complex off-shore fault system structure” (L109), “showcased complex fault geometry scenarios” (146), “community dynamic rupture benchmarks” (169).

Detailed comments and suggestions to improve the reading experience

L35: northern

L37ff (and also abstract): While introducing the tectonic setting of the TFZ and HFF, make sure that geographic features mentioned in the text also appear in figure labels to make sure the readership can follow your descriptions, for example, by referring already here to Figure 1. I would also simplify the descriptions, for example, Nordurland eystra (L48/237) sounds like national description of the region and I would not use it, Kolbeinsey Ridge (KR and NVZ ares never used anymore), Olafsfjördur should be shown in a map. Please revise the text regarding this. For example, the inset in Figure 1a could be increased and the three lineaments could be schematically marked.

L42/3: plate

L45: This sentence sounds somewhat strange.

L52: Please quantify the term “last glacial maximum”

L59: unit missing (years?). Introduce the abbreviation GNSS and GPS. The term GNSS is more general as it covers all positioning systems.

L82ff: I would not abbreviate the word “Section”

L104: I suggest to delete “of active submarine fault systems” and end the sentence with “a submarine earthquake rupture”.

L125: please define *Shmax* in text form not only in line 127 but here.

L155: No brackets needed around Abril et al.

Table 1: Is there a unit missing for Shmax? I would write “150/155” as entry with the asterisk.

L165-167: Repetition of above.

L171: replace “&” with “and”

L173: Please explain “sam(oa)2-flash” already here, not in the consecutive sentence, e.g. by moving “dynamically adaptive, parallel software” one line up. What is the meaning of “parallel software”? That it is able to do parallel computing?

L177: Appendix B is rather short and would add maybe two additional text lines and one equation to the main text. It could be skipped at all (L175-178 already explain the key facts and that its contribution is small) or embedded in the text directly.

L182: delete “so-called”

L188: delete “medium”

L197: Rephrase and start with “The on-fault resolution of 200 m is gradually...”

L210: “A comparison of…” could be deleted, and the figure reference can be moved to the beginning of L212.

L212/Table 27/main comment: 7.9 m slip sounds like too much compared to the estimated slip deficit, if the fault should accommodate 7 mm/yr or so, no, so maybe 1m of slip at most? Can you explain the reason for these high slip values of all models?

L215: Can you explain a bit more? Is it relative to the max. slip observed further down? Is it calculated by the ratio between the area left and right of the curve plotted in Figure A3?

L216/217: Is there a correlation between the spatial pattern observed in off-fault strain (Figure A1) and the SSD, or depth of max. slip? I notice that off-fault strain occurs at constant particular distance to the fault surface trace.

L217: “(Fig. 3b)” (could you zoom into Fig. 3b somewhat to show more details of the flower structure?

L220: delete “are non-negligible” and refer already in this sentence to Figure 5.

L224: refer to Figure 1 here.

L224: Delete “However,”

L227: there is a unneeded bracket left

L228/229: It would help to have the geographic markers under discussion also provided in Figure 5.

L231/232: Given the complexity of the rest of the paper, this explanation of the rake seems to be unnecessary for the targeted audience. You could start the next sentence instead with “Earthquakes on a vertically dipping, right-lateral fault system, such as the HFFS, predominantly exhibit slip rake angles of 180 deg. However…” Also, the sketch in Figure 5 should be updated to show a vertical fault.

L233-235/L329-332/main comment: This agrees very well with InSAR offset observations (unfortunately rarely shown, for example, Ridgecrest, He et al., 2022, Figure 2k, https://doi.org/10.1029/2021JB022779), or slip models that do not constrain the rake angle (e.g. Sarez earthquake, Metzger et al., 2017, Figure S8, http://dx.doi.org/10.1002/2017TC004581, Muji earthquake, Feng et al., 2017, Figure 6, https://doi.org/10.1785/0220170019, or Maduo earthquake,

Xiao et al., 2022, https://doi.org/10.1007/s12583-022-1637-x, Hong et al., 2022, Figure 6, https://doi.org/10.1785/0120210250)

L236: Add reference to Figure 1.

L239: Delete “3D”

L241: I do not understand the benefit of the auxiliary wording of “synthetic tide gauge stations placed near”. Could it not be deleted (also later) and speak of “predicted sea surface height anomaly at the coastal towns of” instead?

L282: What is SuperMUC-NG? Maybe just say “on our computational infrastructure” or so.

L285ff: Technically, the order of mentioning a), b), c), d) should be alphabetically, so exchange the labels b and c.

L294: Revise this sentence, there is a verb missing, I think.

L295: “cross-section to in Figs.”

L3010304: It would be instructive to mark these waveforms directly in subfigures d) and refer to the them here (instead of in the appendix).

L294-L304: Given the length of the text discussing Figures 10-12 and also the information content of the figures (to the untrained eye, at least, subfigures b) and d) look very similar in all cases), you might consider moving two of them to the supporting material?

L300: “Figs. 10b, 11b, 12b, cross-section 1)”

L305-314: You show a panel of 12 figures to only conclude that the waveforms contain more short-period signal. If there is not more to gain from this plot, I would only show two subplots as pars-pro-toto.

L316: “Submarine” instead of “Submerged”?

L317: Rearrange the Sulawesi sentence: “Linked and fully-coupled...modeling of the 2018 … earthquake imply that coseismic…”

L320: No need to repeat what you did, just start with “Our simulations of six rupture scenarios show that the Husavik-Flatey…

L325: Repetition of what you just said in L321, also better say “host a local” instead of “source a localized”.

L332: Replace “In difference” with “Unlike” or “Oppositely to”

L334: Refer to Figure A1 here.

L340: Is there a “so” missing between the wave speed and “we can calculate”?

L340-350: I do not see the benefit of Table 3 as everything is already mentioned here in the text.

L348: Refer to the respective subfigures in Figure 7 here

L353ff: I do not understand: Do you imply that after submarine earthquakes at shallow depths we should be more concerned about acoustic waves rather than tsunami waves?

L394: See my comment for L233-235 resp. L329-332: Yes, the 8 m of slip seems to be too large, but vertical offsets also exist at the end of strike-slip ruptures.

L411: Delete “on-average” or replace it with “relatively”

L415: I cannot guess what kind a “sizeable tsunami” is, maybe you find another term?

L416: Be more specific what you mean by “wto distinct fault system”, e.g. by saying, “a simpler (X segments) and a more complex (55 segments) fault geometry”.

L419: To me 8 m of fault slip seems too unrealistic to point out in the conclusion. It would implicate 800 years of complete slip deficit, no?

Figure/Caption comments

Figure 1 I do not understand the meaning of the percentage of SSD, please explain better, also the meaning of “shallow” in km.

Figure 5 The font is rather small, can you increase it? Also increase the size of the hypocentral star. Use the same symbol (size and color) in Figure 5, 6, 7 10-12.

Figure 7 The figure readability would improve if towns are directly labeled/numbered in the subfigure, instead of describing their location in the caption. Add the hypocenter, similar to Figure 5.

Figure 6 The sketch of the rakes should be adapted to show a vertical fault (incl. slip direction), not a dipping one.

Figure 8/B1 Remove the overarching titles

Figure 9 Increase the font label size. Could you rework the choice of colors (or background color of the legend), such that the individual colors are readable and distinguishable?

Figure 10-12 It would be instructive to non-experts to label the different wave fronts in subfigure d). Flip label b) and c). It took me until reading the conclusions that acoustic waves are “booms” (right?) and not real waves, because in your Figures the color-map is “sea surface vertical velocity [ssvv]”? Please clarify.

Figure B2 The color map is flipped between a) and b).

Supporting Text

When I tested the rupture wavefield videos, some of the started only at the second half of the the video time. Please check.