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Solid Earth
Discussions

Interactive comment on "Fault slip envelope: A new parametric investigation tool for fault slip based on geomechanics and 3D fault geometry" *by* Roger Soliva et al.

Anonymous Referee #2

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General Comments

"Fault slip envelope: A new parametric investigation tool for fault slip based on geomechanics and 3D fault geometry" presents a novel approach to explore parameter space and determine conditions under which a fault or fault system of arbitrary complexity is stable or prone to slip. The method assumes the fault system geometry to be known but accounts for large uncertainties in parameters such as rock properties and subsurface stress state. The authors present a novel method for visualizing the space in which the fault system is stable or not. The underlying scientific foundation is sound, as is the application to the Olkiluoto fault system; however, it is my opinion that the

conclusions are overstated, in addition to several opportunities to improve the clarity and focus of the manuscript.

Specific Comments

The first part of the conclusions is split into four bullets.

1) The first describes a calculation of "Fault probability to slip. . ." In fact, the method of the paper presents nothing probabilistic. The slip envelope is a binary function whether or not a Coulomb yield surface is exceeded for a given combination of parameters. To describe this method as a probabilistic assessment is an overstatement.

2) I do not take issue with the second bullet

3) The final sentence of the third bullet states, "This is particularly useful to address uncertainties in input data for hazard assessment." However, the manuscript only peripherally discusses conventional seismic hazard assessment. To justify this as a key component of the conclusions, further discussion is needed in the manuscript of how this method might be used for hazard assessment.

4) The fourth bullet ("we also propose a proxy. . .") is not clear to me. Yes, the method enables solution of displacement discontinuity for each element of the fault representation, but what is this a proxy for? Overall, the discussion of slip calculations in the manuscript is insufficient (or unnecessary).

The second paragraph of the conclusions is speculative and seems more suited to the introduction than to the conclusions.

The following comments are in no particular order beyond following (roughly) the progression of the manuscript.

The authors present their method as a new and improved alternative to the conventional slip tendency analysis. It is my opinion that this is something of an unfair comparison. If used appropriately, the two methods are based upon different assumptions and should be used for different purposes. Slip tendency analysis (e.g. Morris, et al. 1996) assumes no knowledge of fault orientation but assumes something about rock properties, whereas the method presented in this manuscript assumes fault geometry is precisely described but rock properties are uncertain. This comparison (paragraph beginning line 64 and first sentence of Conclusions, line 342) should be better explained or perhaps revised to discuss how the two methods might compliment each other.

Discussion of the three real fault geometries to which the three real fault systems to which the tool is applied prior to the actual field case could be explained further.

1) In the Landers case, the referenced study is 2D. Presumably the fault geometry used in this 3D study is a vertical downward projection, in which case this should be stated. Are similar assumptions about the down-dip projection made for either of the other two examples? In all of these cases there is likely substantial uncertainty regarding subsurface 3D fault geometry that is not accounted for in this study.

2) The plots of slip tendency for each of these geometric cases is interesting, but some constraint on far-field stress magnitude and orientation should be available in each of these cases. Of course there is uncertainty, but the results might be more geologically insightful if supplemented with some insights regarding what portion of the slip envelope is most geologically plausible.

3) What is the significance of the 5 points (A-E) selected for plotting displacement discontinuity (I believe "displacement" throughout the manuscript should be displacement discontinuity or slip)? Are they end-member examples? Is there further meaning?

4) The paragraph beginning line 237 refers to specific stress orientations. Presumably this is related to a specific fault model (Landers I think). This needs to be clarified. In the paragraph beginning line 246, the authors describe the slip distributions shown in Figure 4. Beyond being a product of the BEM model, the relevance of this paragraph (and Figures 4 & 5) is not clear to me. I think the authors intend to draw a conclusion

out of the slip distributions (and stress perturbations in Figure 5), in which case additional explanation is required. Otherwise, perhaps the material could be omitted. The most extensive discussion of the slip distributions is their limitations, given that better distributions can be obtained from dynamic rupture simulations (Lines 332-338). The same comment applies to Figure 7 and limited discussion thereof.

In lines 258-261, the authors describe other surfaces (pink in figure 6c) that are not slip envelopes

1) The text indicates similar surfaces were shown for the Landers model in Figures 4 & 5. I do not see any such surfaces in any figures relating to Landers, and neither were any surfaces of this sort discussed previously.

2) It is not clear to me from the two sentences discussion that follow what these surfaces add to the analysis or to the manuscript. Further discussion is needed or perhaps the surfaces could be omitted.

For the Olkiluoto fault system case study, the authors make no mention of the orientation of SH or the difference between SH and Sh. The former was a critical variable in the synthetic studies, controlling the sinuous shape of the slip envelopes, and the latter was not discussed but would likely also be important. What are the values? How are they constrained? What are the implications of their uncertainty? These topics could be addressed in Section 3.2 and/or Section 4 and would contribute to the geologic value of the case study.

Typographic corrections and lesser comments

Line 27: an = and ("and mechanical properties.")

Line 63: The authors suggest "the strength of potentially large rock volumes… has never been clearly studied." This is a very strong statement that could be easily contested. Perhaps it would be more appropriate to say there is an opportunity for advancement in this space?

Line 80: Use of “admitted” is ambiguous and confusing. Do you mean that Mohr Coulomb’s theory is well accepted or that its limitations are acknowledged? Line 132-133: Order the references such that there is a clear correlation between the three field sites and the three references.

Line 176: materiel = matierial

Line 176-179: The sentence leading up to eq. 5 is confusing. I expect a sentence that calculates the tectonic constants.

Line 186: I think the reference to Figure 3a is incorrect as the text does not relate to the Landers event. It is not clear to me what figure should be referenced here. Paragraph beginning at line 186: may be more appropriate in the results, and perhaps should be illustrated in a figure.

Line 266 (and elsewhere): the authors refer to “slickenlines” in reference to model results. Slickenlines are technically a specific geologic feature from which slip orientation may be inferred. The lines in figure 7 are not slickenlines but a representation of the orientation of modeled fault slip.

Line 311: Do the authors mean “The planar and vertical shape of the fault slip envelope...”? “... little dependence of fault strength on the vertical load...” implies that the slip envelope is not just planar but also vertical.

Line 319: The authors relate faults smaller than 100m length to displacement [discontinuity] less than 10-2m. Based on the ratio I assume 10-2m would be the seismic slip, but the authors should specify if this relation applies to seismic or geologic (cumulative) slip.

Line 335: chapitre = chapter

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