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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.

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The authors would like to thank the anonymous reviewer 2 for his constructive comments which help to improve the quality of the manuscript.

1) We agree that the term "probability" is not relevant. It has been replaced by "ability" in lines 24, 128, 288 and 367, and removed in several places.

2) The key component of the third bullet point is mentioned in the previous sentence: "first time to propose "fault slip envelopes" which quantify fault system strength magnitude and anisotropy". Rather than developing a hazard assessment section in the

paper, which is not the purpose, we prefer to revise the sentence by replacing "is particularly useful" by "can be useful"(line 27 and 385), which tempers the implications of our results for seismic hazard.

3) To precise exactly what it is done, we replace "propose a proxy" by "calculate fault displacement" (line 387). The way fault displacement is calculated is briefly explained in lines 123-127 (also see lines 102-106) in the method text (section 2.1) and referred to the source paper of the 3D model used in line 124 (Thomas, 1993; Maerten et al., 2010; 2014; 2018) for full explanation. Since fault slip is more important than displacement in this paper, we prefer not to add more details about its calculation to balance the method text, but also because the explanations given refer to the use of the linear elasticity theory applied to 3D dislocation model, which is now quite conventional. Please tell us if you think that more details are needed.

4) We do not see clearly why this text is speculative since the reviewer does not explain why. This text is an extended discussion of the applications of the new tool, which opens to general and concluding remarks, based on the results presented in the paper and other works (see references therein). This especially concerns the main following finding that we must highlight and that is based on our results: fault system strength "results lower for complex fault geometry rather than simple one for equivalent frictional and remote stress condition". To support the fact that this text is mainly based on our results, we have added some references to our figures in the new version of the manuscript (lines 395, 396, and 399). Another option would be to move this text to the end of the discussion, but we actually prefer such a type of opening text in the conclusion, which allow a conclusion not only summarizing the paper results, and then not redundant with abstracts. Please let us know if you think that we should remove this text.

5) A previous comment of an earlier version of this manuscript (submitted to Geology, GSA) suggested to introduce the work with respect to the slip tendency analysis tool and precisely clarify what is new in the presented tool. We actually found worth to

better develop this point, although as mentioned here, these two methods are quite different. We therefore explain the limits of the slip tendency tool (Lines 68-75) that the tool presented can meet. The value of the slip tendency analysis tool is exposed in lines 64-67 and as suggested by the reviewer above, we revised the first sentence of the conclusion to clarify that the two methods are complementary. We however do not agree with the reviewer comment here about the differences mentioned above, since slip tendency assumes that we know fault orientation (otherwise the resolved shear stress would be impossible to calculate) and do not assume knowledge on rock properties (it is only the resolved stresses) (see Morris et al., 1996). The improvements of our method (suggested in the introduction in lines 70-72) are summarized in the revised 4 bullets of the conclusion and exposed briefly/differently here:

1 – Fault slip is calculated using frictional behaviour (not only a stress projection referred to as "slip tendency"),

2 – The tool allows to run thousands of forward simulations in very short time, and therefore to provide full parametric mechanical study,

3 – This tool allows to quantify fault system strength and especially its anisotropy,

4 – Quasi-static fault displacement can be computed for each parametric condition considered.

6) These three geometries were used in earlier studies cited in lines 136. The Landers case was used in Lovely et al. (2009, cited in the previous text) and also Madden et al. (2013, now cited in line 136 and 489-491). The Landers geometry is a 3D surface extruded downward from a 2D Earth's surface trace. The Oseberg Syd geometry is derived from high quality seismic reflexion survey. Uncertainty about 3D fault geometry discretization is not accounted for in this study but is discussed as a limitation in section 4, lines 348-351. All this is now clarified in lines 135-139.

7) The aim of this section of the paper and this Figure is not to provide a deterministic

study, or geologically plausible case (see the Olkiluoto case for this), but to illustrate fault slip envelope and anisotropy strength as a function of fault system complexity using realistic fault geometry (i.e. an improvement of what is shown in Figure 2 with synthetic faults). A deterministic approach, to be presented in such work, requires more geological constraints, especially on triaxial stresses (not uniaxial like here) and rock properties, which are not available for these areas. Instead, we believe that these 3 fault system geometries illustrate in a relevant way some typical fault system geometry found in the Earth's crust. This is now summarized in lines 141-143.

8) We refer here to the four stars (B-E) from Figure 4, selected for plotting quasi-static "fault displacement" (which is the common term, whereas "displacement discontinuity" is reserved to fault surface in dislocation model and "slip" is unclear and generally mentioned in case where displacement is not known – i.e. slip tendency -). The term "displacement" has been precised in line 259. Computed quasi-static fault displacement distribution is shown (bleu stars) for end-member conditions of friction, cohesion and stress orientation with respect to the position of the fault slip envelope. This is now mentioned in lines 261-262 for Figure 4 and lines 296-297 for Figure 7.

9) As mentioned in the line 237 of the previous version, the text refers to "both synthetic and real fault system geometries" (Figures 1, 2 and 3). This is still present in the new manuscript in line 249 and we don't see how to clarify it better.

10) The plot of displacement distribution is a way to analyse in which place fault is prone to slip with respect to different parametric conditions. This was not explained clearly an is now mentioned in lines 258-259. The sentence relative to this, now in lines 263-264, has been rephrased for clarity. Additional information about displacement (and stress distribution) is now presented in lines 266-277 (this text also answers to the comment of reviewer 1 above). Similar text for Figure 7, which is worth to understand why and where faults are prone to slip, was mentioned in lines 265-275 of the previous text and are slightly improved in lines 293-301 of the new version.

11) The text was not referring to these surfaces but to the displacement distribution. This is now clarified in lines 284-285 by removing the non useful and potentially confusing part of this sentence.

12) It was not obvious that the “displacement envelopes” (iso values of maximum displacement in the slip domain) mimic the shape of the fault slip envelope, especially because fault displacement is calculated as a function of fault interaction through their stress field (mentioned in line 125). This is a quite interesting result, which reveals the lesser influence of fault interaction compare to friction, cohesion and stress state considered in this study. The two last sentences now better explain why these envelopes are useful in lines 287-293.

13) We missed to mention the E-W orientation of ïĄşH, which is now indicated in line 164. The values are presented in Figure 6a and the measurement method is fully detailed and discussed in the open access Posiva Report cited as Ask (2011), and briefly mentioned in lines 175-176. The largest part of uncertainty of these measurements presented in this report and mentioned in lines 335-338, is much below the expected stress variation due to the presence of an ice sheet. This was yet mentioned in the previous version of the manuscript and is still present in the discussion in lines 352-354.

14) Typographic corrections and lesser comments

- Corrected

- “has never been clearly studied” has been replaced by “is still a challenge to quantify”.

- “admitted” has been replaced by “accepted”.

- This was yet the case.

- Corrected

- We do not catch the issue in the previous line 176-179. In this sentence we explain how the tectonics constants were calculated (a difference). Please rephrase if you find

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a serious issue, we would be glad to improve the text.

- Yes, “Figure 3a” has been replaced by “Figure 6a”.

- The text now mentions that the faults contain “streamlines representing the orientation of fault slip, referred to as slickenlines” in line 294.

- Yes, this has been added in line 342.

- About less than10-2 m displacement for faults smaller than 100m. This ratio concerns the incremental displacement, not the cumulative. This is now mentioned in line 352.

- Corrected

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Figure 1

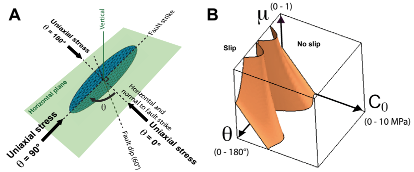

Figure 1 (2 column fitting image). Fault slip envelope of a simple-planar elliptical fault of 60° dip. (a) Scheme of the relationship between fault strike, dip and remote uniaxial stress orientation. (b) Fault slip envelope expressed as static friction (μ), cohesion (C0) and uniaxial stress angle (θ). The stable (No slip) and unstable (Slip) graphical domains are shown on either side of the fault slip envelope.

Fig. 1. Figure 1

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