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Review of “The analysis of slip tendency of major tectonic faults in Germany” by Röckel et al.

Stephen Hicks (Referee)

Referee comment on "The analysis of slip tendency of major tectonic faults in Germany" by Luisa Röckel et al., EGU sphere, <https://doi.org/10.5194/egusphere-2022-26-RC2>, 2022

Review of “The analysis of slip tendency of major tectonic faults in Germany” by Röckel et al.

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(1) Overview of the manuscript

Röckel et al. provide a detailed analysis of slip tendency for mapped faults in Germany using a variety of subsurface datasets. Although local slip tendency studies exist for Germany (e.g., Northeast German Basin - *Moeck et al., 2009, J. Struct. Geol.*; Roer Valley Rift - *Worum et al., 2004, J. Geophys. Res.*), this manuscript presents the first national-scale attempt to my knowledge. The computed slip tendency values are based on regional stress tensor information from an already-published 3D numerical geomechanical model (*Ahlers et al., 2021*). The main findings from this study are that (1) roughly northwest-southeast striking faults have a higher slip tendency in the regional stress field, and (2) there is a reported good spatial correlation between higher slip tendency and seismicity. I congratulate the authors for writing a manuscript with well-grounded objectives and sound, well-described methods. It is refreshing to see these vital fault analyses considered over a large regional scale. The manuscript is detailed, easy to follow, and well-written. Although the methods, data and results appear sound, I have two moderate-to-minor level comments on the comparison with seismicity and the presentation of the regional tectonic context, as detailed below.

I look forward to seeing this excellent work appearing in print soon!

(2) General comments

(2-a) Regional tectonic context and past studies on slip tendency

Although the Introduction reads very well, I feel that it could be improved by including a better description regional tectonic/geological context, especially for a reader who is not familiar with the geology of Germany (like me). Specifically, what are the broad spatial patterns in the regional stress of Germany? What are the main fault structures? What is known about seismicity in Germany and the types of faults that get reactivated? How much of the seismicity in Germany is induced, and what might be the role of high pore fluid pressures in some of these cases? In particular, I feel the article could benefit from having a new figure that comes before all existing figures to present a regional map that highlights and labels specific regions of interest mentioned in the Introduction and throughout the paper (e.g., Roer Graben, Upper Rhine Graben). This map should also show how the stress regime varies across Germany (e.g., by showing indicative SHmax orientations and stress regimes).

Whilst localised slip tendency studies in Germany have been cited (e.g., *Moeck et al., 2009*; *Worum et al., 2004*), it would be helpful to compare the results of these studies with the new slip tendency data from this manuscript.

(2-b) Comparison with seismicity

I am not yet entirely convinced by the comparison between slip tendency and seismicity, which is described in Section 4.5 and illustrated in Figure 11, one of the main conclusions of this study. This concern arises for several reasons, which I describe below, and I try to provide some hopefully helpful suggestions to improve confidence in this conclusion.

(2-b-i) The seismicity catalogue used

Slip tendency is compared with earthquakes based on the *Gruñthal und Wahlstroim* (2012) seismicity catalogue. This catalogue runs until 2006, and locations of the more historical earthquakes are likely to be inaccurate, so I wonder whether this dataset could at least be supplemented with additional earthquakes since 2006 using modern operational catalogues (e.g., EMSC; GFZ-GEOFON; BGR)? Widening the earthquake dataset may help produce more confident correlations with slip tendency. Perhaps if one of these instrumental catalogues were considered on their own, then a lower magnitude threshold could be used, e.g., M_w 2.5-3.0?

(2-b-ii) Comparing small earthquakes and large faults

Given that the best correlation between seismicity and slip tendency is reported for the Andersonian fault dataset, I am curious about the rationale behind selecting a minimum fault length of 250 km for this dataset? Earthquakes down to M_w 3.5 are considered in this analysis, but earthquakes this small would typically rupture a fault length down to tens of metres (e.g., by extrapolating earthquake scaling relations of (*Wells & Coppersmith, 1994*) rather than hundreds of kilometres. Earthquakes in Germany do not typically exceed $M_w \sim 5$. So I wonder whether some of the small earthquakes may occur on more minor faults than currently considered and that may have an orientation not represented by the larger-scale faults. I realise that it is challenging to map every minor fault. Still, I would like to see how the reported slip tendency - seismicity correlation holds up if a more diverse fault dataset encompassing smaller-length faults (e.g., tens of km) is considered instead?

(2-b-iii) Associating earthquakes with faults

As mentioned above, the premise of the reported correlation relies on the implicit assumption that earthquakes are associated with either one of the fault structures considered or a minor fault whose orientation is represented by larger structures. I, therefore, wonder whether any focal mechanism data exists for Germany, from either operational catalogues or existing published studies, that can be used to state whether one of the nodal planes is parallel to the implicitly identified causative fault? I realise that focal mechanism data may be reasonably sparse for an aseismic region like Germany. Yet a quick look at the GFZ-GEOFON catalogue yields a handful of moment tensors for the study area, which could still at least be briefly presented and discussed. But perhaps there are more detailed focal mechanism datasets from local studies across Germany?

(2-b-iv) Presentation of the seismicity – slip tendency correlation

By visually looking at Figure 11, I am not entirely convinced that a spatial correlation exists, so it would be good to quantify the correlation numerically. One idea to consider is to discretise the study area into a grid. Then assign each grid point where a fault and associated slip tendency value exists to its average and/or maximum value and a seismicity parameter (e.g., log of total seismic moment, number of earthquakes, a binary choice of earthquake occurrence within x km radius). This approach would then allow a scatter plot of points to be shown with an associated correlation coefficient value.

(3) Specific, minor comments

(3a) In Figure 2, I find it hard to work out the dip direction of the fault. Could a solid line be possibly added to the fault surface to show the reader where the top of the fault is?

(3b) For Figure 3, the locations of these vertical sections should ideally be shown on a map somewhere – either a previous map or a sub-panel of this figure. Also, the horizontal and vertical scales could benefit from fully labelled axes with a greater frequency of labels and ticks.

(3c) Figure 8 – even though it is implicitly shown in the axis orientation sketch, the caption should also clarify that the map in (a) is from an oblique/perspective viewpoint.

(4) Technical comments

(4a) Line 161 – possibly a word or punctuation missing between “fault set” and “additional histograms”. Maybe a “, with” is needed here?