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Interactive comment on "3D crustal stress state of Western Central Europe according to a data-calibrated geomechanical model – first results" *by* Steffen Ahlers et al.

Anonymous Referee #2

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General

Ahlers et al. present a 3D geomechanical finite element model of Germany and surrounding that has been partly calibrated with observations. They compare calculated crustal stresses with available observations from the World Stress Map and other databases. Overall, the fit is acceptable and allows further analysis and model improvements.

The model seems to be the first step toward a complex model for Germany that can be used for dedicated local and regional stress field modelling. This is of major importance, as Germany restarted the search for a nuclear waste disposal facility, hence this

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model and any successors will be much appreciated and exceptionally helpful.

The modelling approach is well established and has been used by some of the co-authors since many years. It is a combination of the stress models of (mainly) the Karlsruhe group with subsurface models of the GFZ group. The model development as presented in this manuscript was therefore, as I see it, a very easy task (mesh the subsurface structures with Hypermesh - "push" with calibrated values in Abaqus - done). As no time-dependent material is involved, even computation time was likely short, despite more than 1 million elements. Additionally, as observations were partly used as constraints (model boundaries designed after stress orientation, stress values), it is no surprise that the fit of the model to the few available observations is at a good level. The model is thus just a start - but at the same time something that has been missed, which is the most important point on the positive side for this manuscript.

Frankly, I had problems to give my full support for this manuscript as (a) it is only a first and expected result and (b) the values (e.g. as grids in different depth slices in 2 km steps or so) are not even made available for the interested reader on GFZ websites or services like Pangaea.de. Furthermore, the presentation of the study and results can be partly improved, see my many suggestions below. A discussion of your results with previous models, independent if they are simple or not, should also be made.

I would emphatically ask the authors to revise the manuscript along my suggestions and consider publishing results like a gridded 3D stress field over depth, so that the manuscript deserves the role as stand-alone paper.

Specific comments

Title: the title is an example for smart exaggeration, but should be changed. The model and manuscript are part of a German project. You even write in lines 163ff "This area was chosen ... to simplify the definition of boundary conditions later on and with regard to important crustal structures which may affect the recent stress field in Germany... Additionally, model boundaries are selected distal to the German border

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to avoid possible boundary effects in the area of main interest." So Germany is your goal, please use it in the title. Western Central Europe would also include Switzerland as whole, which is not completely part of your model. Also, avoid a phrase like "first results". There won't be a paper with "second results" and even "third results". How about "A data-calibrated geomechanical model for Germany - insights on the 3D crustal stress state".

Abstract: Please avoid citing references. You may use the term Western Central Europe here, but please emphasize that your area of interest is Germany, especially in light of the ongoing nuclear waste disposal location search. Add 2-3 more sentences on results, e.g. on the "salt problem".

L31f: This sentence needs references, e.g. from the search in Switzerland, Sweden and Finland. Add a short introduction on the ongoing search in Germany and why a 3D stress state model of Germany is desired.

L41, first 3D model for Germany: please add a few sentences with references to 3D geomechanical models for other parts of the world.

Section 2.1: should be expanded and more references should be added, e.g., regarding the evolution of the area. Kley & Voigt (2008) will be of help here.

L53/54: Please add reference for this crustal thickness statement (e.g. the works by Gregersen and colleagues or Mazur and colleagues).

L55, Tornquist-Teisseyre Zone and the Thor Suture: this needs more discussion, also in the setup of your model. Looking at Fig. 1b, the Trans European Suture Zone (TESZ) is shown only with the TTZ in Poland and the northern TESZ branch, the STZ in Denmark. In Fig. 1c you show the TESZ with TTZ in Poland (as above) but the more southerly located Thor Suture (southern branch) in Denmark. Nothing is said about the Tornquist Fan in between and the thickness variations here (see the works by Gregersen and colleagues, among others). Which line do you follow in Poland?

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Mazur et al. (2015, Tectonics, https://doi.org/10.1002/2015TC003934) placed it a bit further southwest than commonly done before.

Fig. 1a: Please add a scale of 200 km (representing the search radius you apply later). Change the word "Location" to something more feasible.

Fig. 1b&c: Please update with a more appropriate representation of the whole TESZ. Which TESZ structure is included in the model, the one after Kley & Voigt or the one after Kroner et al.?

Fig. 1: Please increase font size of lat/long numbers.

Section 2.4: I miss a couple of sentences with presentation and discussion of the 3D models shown in Goes et al. (2000, GPC, https://doi.org/10.1016/S0921-8181(01)00057-1) and Warners-Ruckstuhl et al. (2013, GJI, https://doi.org/10.1093/gji/ggt219). These two as well as some in Table 1 should be picked up in the Discussion.

Section 3.1: You should add that you also neglect any remaining rebound effects due to the previous glaciation, see e.g., Brandes et al. (2015, Geology, https://doi.org/10.1130/G36710.1).

L143ff: How is the stress orientation calculated here? Do you use stress2grid for some grid points along a line and then calculate a mean? Which search radius is applied? Or just one coordinate representative for the center point of a boundary? What error can result for the stress orientation?

Section 3.2: You state Germany is your area of interest, and the model has some extension in west-east direction giving you some buffer around Germany. However, in the north-south direction your area of interest is very close to Germany's borders, much closer than in east-west direction. Why? Can any geometry effects be exluded in that direction?

Fig. 4: Avoid rainbow color scale! There are severeal scientific color scales nowadays

available (http://www.fabiocrameri.ch/colourmaps.php). Add that most of the caption information belongs to the subfigures in the lower left. Country borders should also be found in the main subfigures, otherwise it is awkward for the reader to retrieve suitable information from the figure.

L205f: How reliable is the assumption of vertical boundaries here?

Fig. 5: The ALCAPA section in the upper right appears to be much smaller in geographical extent than the one shown in Fig. 1c, where the whole southern part is covered with ALCAPA. Is the line in Fig. 1c misplaced? Did you change your model geometry?

L254f: Although clearly without significance for the result, did you consider to make your model roughly some few 100 metres bigger & smaller in size (as you can roughly pre-calcuclate those extensions and shortenings) so that you get ∼correct coordinates "today"?

Section 4.1., first paragraph: This description irritates the reader. You talk about two grids where you compare nearest grid points? Why don't you calculate the database values on the centre points of the elements in the FE model? Or calculate values from two sources on an identical grid?

L264: Please add reference for this statement.

L265: Please add reference for the <25°. Why not 15° or 22.5°?

L267: Why 5 km?

Fig. 6: I suggest to add two more subfigures. It would be interesting to have a subfigure depicting the number of stress data in each grid point of the WSM grid and one which shows the standard deviation of each grid point. It might help to compare if outliers in the histogram (d) or the map (b) fall together with those.

Fig. 6d indicates that your model needs a stress orientation change of roughly 10°.

Have you tested that?

Figs. 7&8: Suggest to (i) split the quality color in (a) into two each for above and below 1 or 1.5 km, and (ii) color-code the histogram in (c) with the 6 colors so that one can distinguish, especially in Fig. 8c, the different quality and depth sources.

Fig. 9: Please make profile lines thicker. I also suggest to add the RSR over depth to this figure (or create separate figure). In view of this figure, I suggest to calculate the misfit (weighted sum of squared model minus observation difference divided by observation error) for each profile and quantity, and use them in the discussion. Can be even used in future studies with improved models.

Fig. 10: Please use different color scale (not rainbow). Scale should be 0 to 3. I suggest to check earthquake catalogues if focal mechanisms are available for some of these depth slices and plot them too. There are some remarkable edge effects in the upper 4000 m, or shall it be a true thrust mechanism?

Discussion: Please compare your results also to previous models listed in Table 1, but also the values shown in Figures 4 & 10 of Warners-Ruckstuhl et al. (2013).

L400: yet?

L452ff: Here it would be good to have RSR over depth in Fig. 9.

L488ff: Here it would be nice to refer to focal mechanisms in Fig. 10.

Technical comments:

L110: Move '(Fig. 1a)' after 'database' as otherwise the reader thinks your model is shown in Fig. 1a.

L142: initial stress

L259f: Sentence sounds awkward, suggest: 'A mean SHmax orientation is used on a regular 0.5° grid, as we do not use individual data records for this comparison.'

L332: do not

L437: comma after ’(KTB)’

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