**Reply to Referees**

We thank the referees for their comments and suggestions which surely help to clarify our manuscript. In the following we explain how we incorporated their comments into the revised version.

**Answer to Anonymous Referee #1, our answers are written in blue:**

Regarding the region under study, I would recommend to the authors to give more informations on the initial catalog. First, some more details on the quality of the locations, especially at depth (fixed or not), and the magnitudes. Second, it is important to mention if the catalog is discriminated with natural and anthropic events, and how. This is a crucial point.

We added more information about the used catalog in section 3, first paragraph:

As basis for our study we use the earthquake catalog of the LED from 2011 to 2018 for earthquakes within the area close to the ASZ (8.5-9.5° E, 48-48.8° N, Fig. 1b). For these 575 earthquakes we received the bulletin files of the LED (Bulletin-Files des Landeserdbebendienstes B-W, 2018), consisting of hypocenter location, origin time, local magnitude ML and all phase travel time picks with corresponding quality and P-phase polarity. The LED picks from 2011 to 2018 are from 51 LED seismic stations and 14 seismic stations run by other agencies like the state earthquake service of Switzerland (Fig. 1a). Locations are determined with HYPOPLUS, a Hypoinverse variant modified after Oncescu et al. (1996) which allows the usage of a 1.5-D seismic velocity model approach (Stange and Brüstle 2005). Most hypocenter depths could be well determined, but around 9.7% of the depth values were manually fixed. The median uncertainty for longitude, latitude and depth within the catalog are: 0.5 km, 0.6 km, and 2.0 km, respectively. The magnitude ML ranges from 0.0 to 3.4 with average uncertainties of about ±0.2 and the magnitude of completeness is around ML 0.6 (see new Figure S8 in the appendix). The used catalog only contains natural events, as quarry blasts are sorted out and induced events do not occur in the study region.

The catalogue used in this study corresponds to the initial catalog of the LED, complemented by additional pickings. I understand that this would represent another significant work, but I found a bit regrettable to not used the dense temporary network to decrease the completeness magnitude and enlarge the catalogue to get a better spatial distribution of the seismicity with a lower magnitude. Using a simple detection approach and the semi-automatic manual picking would help to improve the dataset.

The detection of small magnitude earthquakes via template matching is current work in progress including location, uncertainty estimation and possible additional fault plane solution determinations. When we did the study presented here, most of our StressTransfer seismic stations only run for a few months in 2018 and we didn't have access to the waveform data of the LED seismic stations yet.

We added a comment section 6:

Thus, we expect another improvement and an increase in detectable events from 2019 onwards due to our additionally installed StressTransfer stations (Fig. 1). Future work will take advantage of the densified seismic station network and focus on small magnitude event detection based on template matching in the area of the ASZ.


In general, the discussion regarding the magnitudes is lacking (also in figure see Figs. 7).

The magnitude values are taken from the LED catalog, these are well determined and cannot be improved within the current uncertainties (±0,2 units). At present we only use magnitude for scaling the size of the fault plane solutions (Fig. 7) and epicenters with magnitude (Fig. 1). As we only took them without changing or complementing anything we don't think a discussion is missing.


In Fig. 1, I am surprised to see so many stations with very few picks.

In Fig. 1 the colors represent the seismic station networks as stated by the legend entries, so permanent (black), StressTransfer (green) or AASN (yellow) and not the number of picks. Maybe you mean Fig. 2? Here, there are many stations with few picks, as Fig. 2 shows the data base used for vp and vs inversion and not the full catalog. The catalog for vp and vs inversion only contains high quality picks, as described in section 4.2 line 174ff. We clarify this in the figure caption of Fig. 2: Seismic stations are indicated as triangles and color-coded with the number of **high quality** picks at a station **used for the vp and vs inversion**.


In Figure 5 as well, the low number of picks (P+S) per event is striking taking into account

the density of the network.

The network shown in Fig 1a is the full network which developed and changed with time. All events in Fig. 5 with yellow colors have 24 and more picks.


I suggest to add the focal mechanisms with the polarities in the Suppl. Mat.

Such a figure is now included in the supplement.

Within the text (section 4.4), I would recommend to modify a bit

around L. 311, because we first think that the authors are doing composite mechanisms.

Because we include SH/P amplitude ratios we no longer use composite fault plane solutions in the revised version.

The authors should mention in the text if the phase amplitudes are also taken

into account in the method they used to determine the nodal planes.

No, they are not included, but we now include SH/P ratios for the revised version of the manuscript. (this was also suggested by reviewer 2)

In section 4.5, all the arguments to chose a strike-slip regime should be included here.

We now include a full stress inversion and changed the text accordingly.

I am not very convinced by the method followed to determined ShMax, which is mainly appropriated for large events. For micro-seismicity, it seems more relevant to consider the stress field in the area under study homogeneous and conduct a inversion of the whole set of

focal mechanisms (e.g., Rivera and Cisternas, 1990; Julien and Cornet, 1989, Michael,

1984, 1984; Hardebeck˘aand Michael, 2006). I am not sure that the spatial variations

of the Shmax direction can be relevant here, as mentioned by the authors. The use

of this large diversity of focal mechanisms probably helps to constrain a stress regime

and stress direction.

We understand your objections regarding the method we used to determine the direction of $S_{Hmax}$, as we mainly have small magnitude events. Originally, we planned to invert for the stress field in future work. However, we include the stress inversion in the revised manuscript as suggested. Accordingly, section 4.5 is reworked completely.

The part of the discussion dealing with the fault plane solution is

unclear. Looking at the Fig 12, it seems that reverse slips occur mainly on the most

dipping planes, which can be surprising, and the authors should explain what his the

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main point of this figure.

We changed this part completely, also using the stress inversion result etc.

I  found that the last section of the discussion could have been

strengthened. After reading it, we do not see what is the contribution of this work to

better understand the stress field of this region.

This section is completely changed including now the new stress field inversion.

Figures: Figure 1: This figure should be improved by increasing the size of the maps

and by adding the corresponding geological background (transparency on shaded topography)

since it is quite developed within the texte (section 2). The epicenters are

either marked by circles or gray dots, why? I would recommend as well to change the

topographic background by adding an illumination on the slope gradients. Add a rectangle

on (a) corresponding to the zone of (b). Add Lake Constance. The magnitude

scale is not appropriate since the large events are indicated by stars. More structural

and tectonic details on (b), it remains unclear.

The map size is increased. We add a separate map with geological background and an illuminated topography as we think that Fig. 1a) is already very full and will become confusing. All seismic events are shown by gray circles, scaled by magnitude, so dots are events where the circle is very small due to a small magnitude. A rectangle is added in Fig. 1a) framing the area of Fig. 1b). Lake Constance was already included in the figure, but we will increase the font size for better visibility. The magnitude scale is shown for the catalog from 2011 to 2018, which is the catalog we will later use in our area. The large events shown as stars happened all before 2011 and are 'historic' events and are not included in the shown earthquake catalog. We will change the figure caption to make it more clear. We show all known and assumed faults in the area of Fig. 1b) but only mark the relevant ones (HZG) and the tectonic features mentioned in the text (LG, SL).

Figure 2: the limits are confusing. I would recommend to keep the same frames than Fig. 1a. Also, the same colors used in Fig. 1a for the stations are also confusing. Use also a shaded topography.

The limits are the same as Fig. 1a) for the area as well as for the topography colorbar. The meaning of the colors of the triangles is clearly stated by the colorbar and the figure caption.

Indicate the station MSS (the white triangle is not visible in Fig 6).

The size of the white triangle is now increased.

Figure 7: the magnitude scale is required

A magnitude scale is now included.

Figure 8: indicate the area of study and indicate differently your data.

Done.

Figure 10 and 11 should be combined into only one.

We tried to combine both figures but due to their different orientations of the long axis this was not successful. Thus we prefer to keep them separately.

Minor comments:

L. 14: tone down this sentence by removing only, some geophysical imaging and paleo-seismological studies could help as well.

Changed:

New: as there are no visible surface ruptures, which may be connected to the fault zone, we study its characteristics by its seismicity distribution and faulting pattern.

L. 45: major damage: what kind?

Now added:

Although the earthquakes caused major damage to buildings such as fractures in walls and damaged roofs or chimneys, no surface ruptures have been found or described (e.g. Schneider, 1971).

L.47: its geometry. Unclear, if you mean geometry of the seismicity, this is not correct. I would change into to derive the geometry, the segmentation of the faulting pattern.

Changed:

For this reason, the ASZ can only be analyzed by its seismicity to derive the geometry, possible segmentation, and faulting pattern.

L. 49: you mean aprior large earthquakes?

Changed:

L. 51: add 'temporary'

Changed:

Since 2005 the seismic station network of the state earthquake service of Baden-Württemberg (LED) was changed and extended (Stange, 2018) and in summer 2015 the installation of the temporary Alp Array Seismic Network (AASN) started (Hetényi et al., 2018).

L. 58: remove minimum here, this is confusing for the Introduction

Changed:

We calculate a new 1-D seismic velocity model and relocate the events.

L. 59: change geometry of the ASZ into the geometry of the fault pattern at depth in the ASZ

Changed

L. 60: remove permanent

Changed:

L. 84: It is not clear if it is the current or past stress field ?

Changed:

The current regional stress field of southwest Germany is dominated by an average horizontal stress orientation of 150° (e.g. Müller et al., 1992, Reinecker et al., 2010, Heidbach et al., 2016) and was determined from focal mechanism solutions, overcoring, borehole breakouts, and hydraulic fracturing (e.g. Kastrup et al., 2004, Reiter et al., 2015, Heidbach et al., 2016).

L. 94: The directions of the current principal stresses are constant, the amplitudes are not constrained.

We changed the sentence to:

The direction of $S_{Hmax}$ in our research area is quite constant, except of an area directly south of the HZG (Albstadt-Truchtelfingen) and an area within the HZG (Albstadt-Onstmettingen). There the $S_{Hmax}$ direction rotates about 20° counterclockwise into the strike direction of the HZG (130°, Baumann, 1986), which may be caused by a reduced marginal shear resistance.

L. 104: en echelon features compensating the displacements of the ASZ: I am not sure to understand.

With en echelon features we mean graben structures which open in a steplike arrangement at the surface above a partly decoupled strike-slip fault (see Reinecker and Schneider 2002 or Tron and Brun 1991). The tectonic model of Reinecker and Schneider (2002) connects the visible graben structures at the surface (like the HZG) with the ASZ.

Changed text:

L 104: Reinecker and Schneider (2002) propose a tectonic model to relate the graben structures with the ASZ below. They apply the result of Tron and Brun (1991) who showed that the movement of a partly decoupled strike-slip fault in the subsurface can generate graben structures at the surface in a steplike arrangement. In the regional tectonic model the graben structures are the HZG, the Rottenburg Flexure, western Lake Constance faults, and the Fildergraben (Reinecker and Schneider, 2002). The ASZ itself is the strike-slip fault, partly decoupled from the surface by a layer of Middle Triassic evaporites in the overlying sedimentary layers (Reinecker and Schneider, 2002). Stange and Brüstle (2005) consider the bottom of the Mesozoic sediments as mechanical decoupling horizon as no earthquakes occur above 2 km depth.

L.112: moderate displacements : recent, Quaternary?

We now added: ca. 5 Myr according to Reicherter et al. (2008)

L. 115: Add (Fig. 1a) after Lake Constance.

Changed:

Wetzel and Franzke (2003) identified a 5-10 km broad zone of lineations along the 9 °E meridian striking predominantly N-S, NW–SW and ENE-WSE pursuable from Stuttgart in the north to Lake Constance in the south (Fig. 1a).

L. 116: change limit into limited

Changed:

L. 116 to 119: these lines should be reformulated, they are unclear.

Changed to:

Along the 9°E meridian Wetzel and Franzke (2003) identified a 5-10 km broad zone of lineations pursuable from Stuttgart in the north to Lake Constance in the south (Fig. 1a). Those lineations strike predominantly N-S, NW-SW and ENE-WSW. The N-S and ENE-WSW striking faults limited the NW-SE striking graben structures, like the HZG (Reicherter et al., 2008). The NW-Se striking faults are expected to be possibly active at intersections with N-S striking faults due to a reduction in shear resistance accompanied by aseismic creep (Schneider, 1979, Schneider, 1993, Wetzel and Franzke, 2003).

L. 127, 173, 435 + caption_Fig12: remove th and nd to the dates.

These are removed now.

L. 128: add respectively

Changed:

L. 128-129: The average: This is coseismic slip rates. Mention from which data they are deduced. The same for the return period, mention briefly how this is estimated.

Added:

The average seismic dislocation rates along the ASZ are on the order of 0.1 mm/a (Schneider, 1993). The return period of M=5 earthquakes along the ASZ is approximately 1000 years (Schneider, 1980, Reinecker and Schneider, 2002). Both estimates are based on historic earthquake records.

L. 132: change in a depth into at a depth

Changed

L. 134: the term extension is confusing here (lateral extend)

Changed to:

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The lateral extend of the fault zone in N-S direction is still under debate:

L. 142: at the beginning of the summer.

Changed:

Additionally, within the AlpArray Project (Hetényi et al., 2018), nine seismic stations were installed starting in summer 2015 within 80 km distance to the ASZ, four of them directly around the ASZ (AlpArray Seismic Network, 2015, Fig. 1b).

L. 158-159: Clarify the error boundaries are checked.

Changed:

Finally, the uncertainty boundaries are checked by eye, and the phase pick is done manually between the two uncertainty boundaries.

L. 180-181: give more explanations.

Now changed in the revised manuscript

L. 206 : a few: :

Changed

L. 222: layers

Changed:

L. 226: no event

Changed

L. 239: the Stress Transfer stations from 2018

Changed

L. 367, 368: writhe the same number of decimals.

Changed:

The determined seismic velocities increase with depth and they are well constrained between 2.50 km and 18.25 km depth (Table 1). The layers between -2.00 km to 2.50 km depth are not very stable due to the non-uniform distribution of rays and sources.

L. 429-431: not necessary. And check consistency with the Fig 12, where

rake varies between -65 and +65_, why?

Done, note we redetermined the fault plane solutions using amplitude ratios.

**Answer to Referee 2, our answers are written in blue:**

1. Focal mechanisms and stress field in SW Germany: When talking about stress field

in SW Germany (line 83 – 86) it would be appropriate from my point of view to also

reference the paper by Plenefisch & Bonjer (1997) and Bonjer (1997) who inferred the

stress field of the Southern Rhine graben area by the inversion of 40 focal mechanisms

determined by themselves (Bonjer 1997).

We included the mentioned papers.

See section 2: The regional stress field of southwest Germany is dominated by an average horizontal stress orientation of 150° (e.g. Müller et al., 1992, Plenefisch & Bonjer (1997), Reinecker et al., 2010, Heidbach et al., 2016) and was determined from focal mechanism solutions, overcoring, borehole breakouts and hydraulic fracturing (e.g. Kastrup et al., 2004, Bonjer (1997), Plenefisch & Bonjer (1997), Reiter et al., 2015, Heidbach et al., 2016). It is characterized by NW-SE horizontal compression and NE-SW extension (e.g. Kastrup et al., 2004) and developed during late Miocene (Becker 1993).

2. Presentation of the FOCMEC results: I wonder why the authors do not show any

figures with the original output of the FOCMEC program, this means stereographic

plots with used polarities and the calculated fault planes that are in accordance with

the polarities. This is usual practice and gives the reader an impression about the

distribution of the input data and the resulting and suitable pairs of fault planes. I

suggest here to show a figure with the results for at least two or three earthquakes with

different quality factors (after Table 3). The solutions for the other events or clusters

respectively could be given either in the supplements or event better - since altogether

these are 'only' 14 solutions - in one comprehensive figure in the paper itself. I think

this is a must. I am aware of the fact that figure S5 shows the uncertainties in strike,

dip and rake. This is a nice figure, but it does not replace the figure I proposed above.

Figures with polarities and fault plane solution fits are now included in the revised manuscript, see
supplement.


3. Relative weighting and unity weighting: Please, describe shortly in the text, what is

the difference between these two weighting approaches.

New text in section 4.4:

To find the appropriate solution one can allow different types of errors in FOCMEC. We compare the
relative weighting mode and the unity weighting mode of the FOCMEC inversion for all events. This
is done to explore if the results differ significantly what could mean that they are questionable (Snoke,
2003). In the unity weighting mode each wrong polarity in the FOCMEC solution counts as an error of
one. In the relative weighting mode, polarity errors near a nodal plane count less than polarity errors in
the middle of a quadrant. Thus the polarity errors are weighted with respect to their distance to the
nodal planes. This means a wrong polarity is weighted by the calculated absolute value of the radiation
factor (ranging between 0 and 1). For both modes we searched for solutions allowing increasing
errors varying systematically the different possible errors. Those are errors in the P-polarities, errors in
the SH-polarities and the total error of wrong SH/P amplitude ratios, as well as the error range in
which they are expected to be right. For example, we consider the unity weighting mode and an event
with P- and SH-polarities. First, we check if we get a solution for zero errors both. If not we increase
the allowed errors for the SH-polarities to one, as the SH-polarities are more unsecure than the P-
polarities. If this still doesn't get a solution we check for a wrong P-polarity and no wrong SH-
polarity. This procedure is done for unity weighting and relative weighting and stopped if a solution is
found. To check for a dependency of the result on a single pick, the next runs for higher errors are also
determined.


4. SH polarities: In line 306 the authors state that in some cases they could determine

SH polarities. After all these are 27 events according to Table 3. Since these SH

polarities could be determined I assume that one could also determine amplitude ratios

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of SH/P and use them as input in the FOCMEC inversion. The use of amplitude ratios

is scheduled in FOCMEC. It puts further constraints on the solutions and provides

an easy way to determine one single solution by minimizing the differences between

measured and calculated ratios. Why didn't you use such ratios, please comment on

this topic. Perhaps the use of amplitude ratios could help in case of a small number of

polarity observations and could made cluster analysis needless.

We now include the amplitude ratios in the revised version of the manuscript and discuss their usage.


5. Missing a real inversion for the stress tensor: P-, T-and B-axis of a focal mechanism

represent the strain axes. Only in case of a new fracture the strain axes automatically

represent the principal stress axes. However, in case of a preexisting zone of weakness,

which is commonly assumed for small size earthquakes, P-, T- and B-axes do

not usually represent the principal stress axes. It is only the direction of the slip vector

which is constrained by the orientation of the principal stress axes and the relative

stress magnitude. An inversion of an ensemble of slip vectors finally allows the determination

of the stress field and the strike of minimum or maximum horizontal stress

axis respectively. I am not really convinced by the way Mader et al. determine their orientations

of SHmax. I wonder why they have not performed a 'real' stress inversion of

their focal mechanisms. There are several programs to do this (e.g. Gephart & Forsyth,

1984; Rivera and Cisternas, 1990; Michael, 1984; Hardebeck & Michael, 2006). I think

this should be done before digging deeper into the interpretation of the stress field

in and around the ASZ, even though I assume that the results will not dramatically

change. The diversity of the focal mechanisms of the individual clusters which is obvious

from Fig. 7 and Table 3 fulfills one essential requirement of a successful stress

tensor inversion.

We now include a stress inversion in the revised manuscript and discuss its usage and implications.