Comments from the Guest Editor

Editor: Please check the years of historical EAF earthquakes on line 59, in particular the event cited as 1975 (do you mean 1905?) As one of Reviewer B also points out, there are also some earlier (and larger) earthquakes documented by Ambraseys that you could also discuss here and around lines 294-296 . At around line 308, the 1905 earthquake — summized to have ruptured west of Puturge — is especially relevant, but it is not mentioned at all.

Reply: Thank you for catching these errors. 1975 is a typographic error and should be 1795. We now mention the 1905 earthquake in the revised text

"The EAF featured several notable earthquakes during the last century, with the 1905 Mw 6.8, the 1971 Mw 6.7, the 2010 Mw 6.1, and the 2020 Mw 6.8 earthquakes, but the section south of Elazig has remained locked for more than a century (Hubert et al. 2020, Duman & Emre 2013)."

We also mention the 1114 earthquake in the revised text

"Previous large earthquakes in this section include the 1114 M 6.9, 1795 Mw 7.0, 1872 Mw 7.2, and 1893 Mw 7.1 ruptures (Ambraseys 2009, Guvercin et al. 2022), all bounded by major (releasing) fault bends (Duman & Emre 2013)."

Editor: You describe the EAF as "immature" (line 49) but it has a much larger cumulative offset (well documented by Duman & Emre, 2013) than some other recent well-studied earthquakes (e.g. Ridgecrest, Landers) and on this basis might better be described as of intermediate maturity. Either way, it would be worth spending a sentence or two describing what you mean by fault structural maturity and then place the EAF a little more precisely on this spectrum.

Reply: We changed the text to

"The EAF, a conjugate, 300 km-long left-lateral fault, extends southwards and branches out diffusely to the Dead Sea Fault (DSF) and the Cyprus Arc to the southwest (Duman & Emre 2013). The EAF connects multiple segments with a low long-term slip rate (Aktug et al. 2016, Cavalie & Jonsson 2014) separated by major releasing bends and step-overs (Duman & Emre 2013), making it comparatively more immature than the NAF (Wesnousky 1988)."

Editor: In the Discussion of seismogenic and seismic depth ranges, it would be worth describing the "background" seismic layer thickness along the EAF, i.e. as measured prior to the 2023 sequence. For example, Pousse-Beltran et al. (2020) relocated seismicity along the full length of the EAF and found calibrated focal depths to be >20 km everywhere (see their supplement for depth histograms). This is one of a number of relevant studies you could cite.

Reply: We added the background seismicity in Figure 6. The distribution of aftershocks follows the distribution of background seismicity from Pousse-Beltran et al. (2020).

Editor: Finally, please ensure that your model fault geometries and slip distributions are fully tabulated as supplementary data files or supplementary tables, for reproducibility and usability.

Reply: The fault geometry and slip distribution for the Mw 7.8 Kahramanmaras mainshock, the Mw 7.6 Elbistan aftershock, and the Mw 6.5 Antakya aftershock are readily available on the zenodo.org repository at this link: https://doi.org/10.5281/zenodo.7747846, as indicated in the "Data availability" section.

Comments from External Reviewer

Reviewer B: In this paper, Barbot and coauthors propose one of the first slip distribution based on geodetic data for the two large earthquakes that shook Turkey and northern Syria in February 2023. The authors first describe briefly the area, move on to a description of the data and the modeling strategy, described the model and propose some lines of discussion, relating these earthquakes with ongoing discussions about earthquakes in general and about seismic hazard in the area. In general, the paper reads nicely and the nice figures convey the message of the paper. I have almost no serious comments to make as, in my opinion, the science is standard and nicely done. This paper should be, in my opinion, accepted quickly.

Please find below a list of the few and minor comments I have.

Reply: Thank you for your carefully read of the manuscript and for your constructive comments.

Reviewer B: Line 44: Although I appreciate you citing my papers, I suspect you have the wrong Jolivet here (Jolivet Senior is probably the one you should cite here).

Reply: Thank you for catching this error. We now cite Laurent Jolivet et al. (2013).

Reviewer B: Line 56 and last paragraphs of the discussion: The last historical event that was widely felt across the entire middle east probably dates back to Nov 13th, 1114 (see page 282 of Earthquakes in the Eastern Mediterranean and the MIddle East, Ambraseys, Cambridge Press. Let me know if you cannot get your hands on a copy, I can share a pdf version). Although this is quite speculative, it seems this 1114 earthquake was larger than the ones you described from the 18th and 19th centuries.

Reply: We changed the text to

"*Previous large earthquakes in this section include the 1114 M 6.9, 1795 Mw 7.0, 1872 Mw 7.2, and 1893 Mw 7.1 ruptures (Ambraseys 2009, Guvercin et al. 2022), all bounded by major (releasing) fault bends (Duman & Emre 2013).*"

Reviewer B: It would be nice to cite Guvercin et al 2022: Güvercin, S. E., Karabulut, H., Konca, A. Ö., Doğan, U., & Ergintav, S. (2022) Active seismotectonics of the East Anatolian Fault *Geophysical Journal International*, 230, 1, 50--69

Reply: We now cite Guvercin et al. (2022).

Reviewer B: Figure 1: Caption is incomplete. Some lines are not described. Please cite source for topography.

Reply: We updated the caption with the following text:

"The EAF and Dead Sea Fault (DSF), plate-boundary faults are shown in red. Major and minor faults are shown in thick and thin black lines, respectively (Emre et al. 2018). The focal mechanisms are from the AFAD for the day of February 6, 2023 (https://deprem.afad.gov.tr/event-catalog). The topography is from the Global Multi-Resolution Topography Synthesis (GMRT) v3.7 (Ryan et al. 2009)."

Reviewer B: Line 82: A few other papers have proposed some slip distributions for the Elazig earthquake and deserve to be cited here. Please consider papers by Ragon et al or Konca et al.

Reply: We now cite Ragon et al. (2021) and Konca et al. (2021).

Reviewer B: Line 111-114: It would be nice to have figures of the GNSS time series to illustrate the estimation of the coseismic offset (supplementary information would be enough).

Reply: Figure S1 shows the time series of 9 different stations for the horizontal component of displacement. We also added Table S1 with the three-dimensional coseismic offsets for each station considered.

Reviewer B: Line 152: In general for the Satellite data, please indicate the threshold chosen for masking of data (and the software corresponding as different SAR softwares propose different ways of estimating coherence, for instance).

Reply: We added the following text "*For the purpose of inversion, we ignore the regions with a correlation coefficient lower than 0.3.*"

Reviewer B: Line 195: Could you please show some rougher/smoother models in the supplementary informations to allow readers to assess your choice? Maybe some key features in the residuals would also help to grasp the reason of the choice on the L-curve. Please show the said L-curve.

Reply: We add two figures showing the trade-off between smoothing and residuals in supplementary materials. This includes finite slip distributions of the Mw 7.8 mainshock and Mw 7.6 aftershock for different smoothing weights.

Reviewer B: Line 202: Figures showing data, model predictions and residuals should be larger in supplementary information. For instance, it seems that slip is slightly underestimated on the westernmost branch of the M7.5 second quake (Sürgu fault?) as some systematic residuals show up in the range offset of track 116. Larger figures would be much nicer.

Reply: We updated the manuscript with the full-resolution images. There are residuals for some datasets (e.g., track 116), but they are not systematically found in others. For example, there is only negligible residuals in the near field for tracks 14 and 21.

Reviewer B: Line 217 and Fig 6: I had a bit of a hard time going back and forth between figures and text as the names of the segments are not always straightforward. If possible, it would be nice to have these on Fig 6 to help readers who are not familiar with the area.

Reply: We updated Figure 6 accordingly.

Reviewer B: Line 291: This sentence reads awkward. First, there is the question of the model smoothing. Then, if the velocity-strengthening region slipped coseismically, then, locally, stress drop is negative, which is physically unsound.

Reply: Thank you for this comment. It is common for ruptures to spread into a velocity-strengthening region. This indeed leads to local positive stress change. We clarified our statement with the following text:

"*We speculate that the seismogenic zone extends from 4 to 10 km depth in this region and that the coseismic slip that occurred outside these bounds took place in a nominally rate-strengthening region of the fault. Coseismic slip commonly propagates in regions of stable sliding because of dynamic effects (Barbot et al. 2012, Noda & Lapusta 2013, Salman et al. 2017, Barbot 2019b, Nanjundiah et al. 2020).*"

Reviewer B: How about such patterns actually reveals that the image you give for the distribution of rate-dependent frictional properties is valid for the interseismic and post-seismic periods, but that it does not really apply when slip speed reaches high values? I have sometimes been puzzled by the liberty taken in extrapolating lab measurements to higher slip speeds for earthquake cycle models. When slip speed gets in the seismic range, rupture involves additional mechanisms such as thermal pressurization or even melting in places, mechanisms that are not represented in the classic rate-and-state friction formalism (as shown by Di Toro et al 2010). So, in the end, the discussion about strengthening vs. weakening when only considering a coseismic event is, in my opinion, a bit uncertain and should be taken with greater care than in this discussion, although I appreciate always a bit of mechanical insight in an earthquake report paper!

Reply: Thank you for this interesting comment. We added the following sentences:

"*In contrast, the seismogenic zone is controlled by the stability of frictional sliding (Blanpied et al. 1995), which may be entirely controlled by the distribution of frictional properties (Ruina 1983, Rice & Ruina 1983, Rubin & Ampuero 2005, Barbot 2019b, Wang & Barbot 2020, Wang & Barbot 2023).*"

and

"*The coseismic slip distribution constrains the depth of the seismogenic zone. However, during the rupture of large earthquakes, coseismic slip propagates into the velocity-strengthening domains due to the concentration of static and dynamic stresses near the free surface (e.g.,* *Barbot et al. 2012, Jiang & Lapusta 2016, Jiang et al. 2022) and is affected by enhanced weakening mechanisms (Di Toro et al. 2011). As a result, the unstable-weakening region that forms the seismogenic zone is presumably much narrower than the depth extent of coseismic slip."*

Reviewer B: Looking forward to read this paper in Seismica!

Reply: Thank you for your useful comments and positive review.

Comments from Production Editor

Reviewer C: L46: I am not sure what the "Main Recent Fault" is and why each word is capitalised like a proper noun.

Reply: This is the name of the fault that separates Arabia from Iran. We added the references to Talebian & Jackson (2002), Vernant et al. (2004) and Reilinger et al. (2006) accordingly. For your reference, please see also the recent work

Watson, A.R., Elliott, J.R. and Walters, R.J., 2022. Interseismic strain accumulation across the Main Recent Fault, SW Iran, from Sentinel-1 Insar Observations. *Journal of Geophysical Research: Solid Earth*, *127*(2), p.e2021JB022674.

Reviewer C: - L78: Was the fault geometry based on the aftershocks, or is this sentence just saying that a vertical projection down from surface traces matches the aftershock distribution?

Reply: For clarity, we changed the sentence to

"*We ensure that the fault geometry at depth follows the distribution of relocated aftershocks (Lomax 2023).*"

Reviewer C: - L91: This section should be labelled section "2" and the Introduction should be labelled section "1". Please check for consistency.

Reply: Fixed accordingly.

Reviewer C: - L266-268: I am not sure what is meant by this sentence about the 2km-thick zone. Please consider re-wording.

Reply: We changed to

"*However, the spatial resolution of the geodetic data considered is limited to 2 km, and we cannot resolve the distribution of deformation below this length scale.*"

Reviewer C: - L269: Consider changing "wider depth" to "greater depth range" to ensure that there is no confusion fault-perpendicular dimensions.

Reply: We changed the sentence accordingly.

Reviewer C: - L282-283: Is it possible that the aftershock depth distribution is biased by the seismic network coverage? Is the seismic network dense enough to record earthquakes at shallow depths (e.g., <5 km) – to resolve such shallow depths, we would need to closest stations to be located <10 km epicentral distance away.

Reply: We changed the text to

"Despite uncertainties in hypocenter location due to a spare seismic network, the distribution of aftershocks exhibits a remarkable complementarity with the distribution of coseismic slip, surrounding the regions of high slip, but also concentrating at segment boundaries."

Reviewer C: - L286: Please clarify what is meant by a "new fault structure" here. E.g., Newly formed? Newly mapped? Newly ruptured?

Reply: We changed to "*previously unidentified fault.*"

Reviewer C: - L287-291: Can we speculate as to why the seismogenic/seismic zone for the M7.6 aftershock cover a smaller depth range than the M7.8? In other words, why might the rate-strengthening/-weakening zones be different?

Reply: We added the following statement:

"The lateral variations in the depth extent of aftershocks may be associated with differences in hydrothermal conditions, such as geothermal gradients and pore fluid pressure, or with different compositions of the fault zones."

Reviewer C: - L337-338: maybe needs a small clarification to compare understanding of seismic hazard between immature and mature fault systems. This clarification could come earlier in the manuscript.

Reply: We added the following statement in the introduction:

"The EAF connects multiple segments with a low long-term slip rate (Aktug et al. 2016, Cavalie & Jonsson 2014) separated by major releasing bends and step-overs (Duman & Emre 2013, Guvercin et al. 2022), making it relatively immature compared to the NAF and other continental strike-slip faults (Wesnousky 1988)."

Reviewer C: - In my view, Figure 1a and Figure 2 could be combined into a single panel as they show similar information.

Reply: We agree that they have similar information, but we would like to maximize their individual size so that the reader can easily find the relevant information. With your permission, we would like to keep Figures 1 and 2 separate.

Reviewer C: - Figure 2 caption: why is "Fault" abbreviated to "F." in some cases?

Reply: We added the following clarification in the caption of Figure 2

"Fault is abbreviated to ``F." to save space."

Reviewer C: - References: Consider also citing the following preprints on the Turkey earthquake rupture processes: Zaharanik et al.: https://eartharxiv.org/repository/view/5127/ Rosakis et al.: https://eartharxiv.org/repository/view/5042/ o Okuwaki et al.: https://eartharxiv.org/repository/view/5106/

Reply: We would gladly cite these studies once they are sanctioned by peer-review and accepted for publication.