Response to reviewers for "Sub- and super-shear ruptures during the 2023 *Mw* 7.8 and *Mw* 7.6 earthquake doublet in SE Türkiye" by Melgar et al. and submitted to Seismica

Thanks to all reviewers for helpful comments. Our responses to each are in **blue**

Reviewer A

Melgar et al. investigated the recent earthquakes in Turkey. They compiled a catalog of relocated aftershock events and further developed rupture models for the Mw 7.8 and Mw 7.6 earthquakes. The rupture models were infered through the inversion of high-rate real-time Global Navigation Satellite Systems (HR-GNSS) and strong-motion data. In the inversions, they considered multi-fault and 3D fault geometry. Their key findings are as follows. The first event nucleated on a previously unmapped fault and progressed on the East Anatolian Fault with the rupture extending about 350 km. The second event ruptured the Sürgü fault extending about 160 km. The first event had a maximum rupture velocity of 3.2 km/s, while the second one had a super-shear rupture of 4.8 km/s westward but a sub-shear rupture of 2.8 km/s eastward. These events associated maximum fault displacements as large as ~8m and ~6m, respectively. They suggested that these exceptional rupture characteristics are consistent with the observed large ground shaking levels.

First, let me congratulate the authors for the very timely manuscript that provides critical scientific insights into the rupture properties of devastating earthquakes (well-aligned to the scope of Seismica). Their findings are crucial to understand the observed ground shaking levels. The manuscript is well-written, precise, and easy to understand. It is also commendable that the authors make the data and models accessible.

However, there are a few concerns requiring clarifications (indicated in the list of comment given below). I believe that these are minor and the authors can quickly revise their manuscript to incorporate these clarifications. I also request the authors to improve the writing wherever possible when they revised their manuscript - more specifically to take care of the tense - either past or present but not both in describing their present analyses. I believe this manuscript was hurriedly written and hence, most comments relate to the writing. I hope that the comments listed below will be useful to the authors in revising their manuscript.

1. Abstract - Line 36: "EAFZ" abbreviation is not needed here.

Modified as requested

2. Abstract - Line 37: "signficant ground motions" - would it be possible to provide a measure of that - for example, recorded maximum peak ground acceleration.

Modified as requested

3. Line 40: "...kinematic inversion of HR-GNSS and ..." - is it kinematic inversion of combined (or joint) HR-GNSS and ...

Modified as requested

4. Line 40: "...multi-fault, 3D geometry" - perhaps, multi-fault and 3D rupture geometry?

Modified as requested

5. Line 45: "Peak slip" - perhaps, maximum slip. Peak slip is more often used with source-time functions.

Not sure we see the difference but we modified as requested

6. Line 72: "… important to understand the nature of …" , perhaps "explains"

Modified as requested

7. Line 72: instead of " shaking " , "ground shaking" would be be more accurate.

Modified as requested

8. earthquake doublet". The authors consider these earthquakes as a "doublet" rather

than a traditional mainshock/aftershock sequence.

We refer to the occurrence of those very large events on different faults within a time interval of 9 hrs, its event has its own aftershocks (see Fig. 1)

9. Line 69: "…large motions .." perhaps, " displacements".

Modified as requested

10. Line 70: "the magnitude 7.6" . perhaps, "the magnitude 7.6 event ruptured extremely quickly …." .

Modified

11. Line 72: "important to understand the nature of why" .. perhaps, " important to explain why …".

Modified as requested

12. Line 72: "shaking" … "ground shaking"

Modified as requested

13. Line 77: instead of h, perhaps "depth" (also, in Line 80)

Modified as requested

14. Line 86: "time of writing".. "time of writing this article"

Modified as requested

15. Figure 1 caption. The abbreviation are not needed. It seems that Figures 1a and b have same axis but the latter is displayed with smaller image. This can be fixed so that both plots have same display size.

Removed the abbreviations. Both corss sections are plotted with identical scale factors the difference arises because cross-section aa' is longer than bb'

16. Line 101: "The EAFZ", instead of East Anatolian Faul Zone.

Modified as requested

17. Line 102: It would be simple to write - "The tectonics are complex …. "

Modified as requested

18. Line 120: "We will show that, for the Mw 7.8 the kinematics are complex..", perhaps -

"We will show that, for the Mw 7.8 event, the kinematics are complex …"

Modified as requested

19. Line 130: "We produce relative locations for a total .." or "We relocate a total …"

Modified as requested

20. Line 130: “ The data” - please clarify what data?

Added “phase data”

21. Line 144: “This overcomes ..” perhaps, “This approach …”

Modified as requested

22. Line 147-149. What do the authors meant by “links”.. Is it connections considered for selection of neighbouring stations?

We changed the wording to “connections” like so: “Travel-time differences are estimated for event pairs with less than 10 km of interevent distances and with a minimum of 8 connections to define up to 10 neighbors at all 177 stations located within 200 km distance from the center of cluster.”

23. Line 152: “We took” .. perhaps - “We apply …” or “We use …”

Modified to “we employed”

24. Line 158: “Given the complexity of the events …” perhaps, “Given the rupture complexity of the events….”

Modified to “Given the complexity of the rupture process of both events”

25. Line 161: “infer”… perhaps, “inferred”?

Modified as requested

26. Line 190. “MudPy code” - If this code has been already used previously, please

mention it and provide a reference.

The reference is already immediately following the mention (Melgar & Bock, 2015) and the github repo and zenodo snapshot are in the data section at the end.

27. The frequency-wavenumber integration approach of Zhu and Rivera (2002) considers point source. Please provide clarifications as to how it was adopted for the finite-fault rupture model.

Each triangle is assumed to be composed of several sources. We added the text: “with the sum of point sources used to represent each subfaults finite extent (see Koch et al., for an example of this)”

28. Figure 2. Caption - “RMS” .. “Root Mean Square (RMS)”

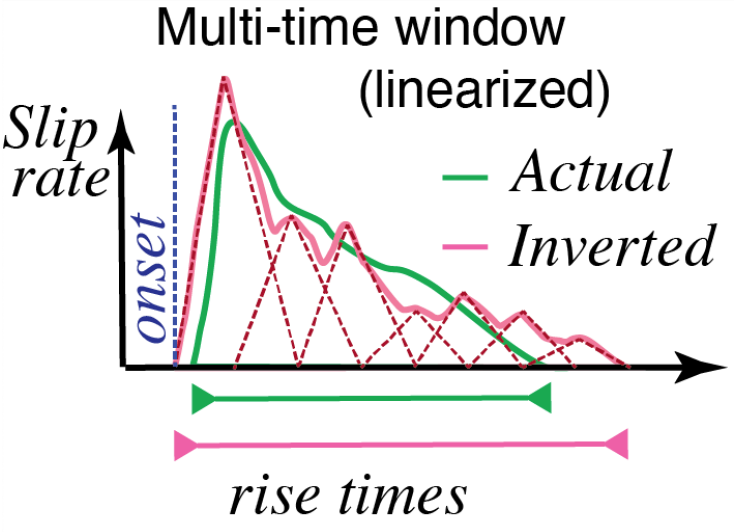
Modified as requested

29. Figure 2. Caption - “Best fitting values are 3.2 km/s for the Mw 7.8 and 2.8 and 5.0 km/s for the Mw 7.6.” … perhaps, “Best fitting values are 3.2 km/s for the Mw 7.8 event and 2.8 and 5.0 km/s for the Mw 7.6 event.”

Modified as requested

30. Line 201: A triangular slip rate function with fixed rise-time is contrary to a multi-window approach. Is it that this description of using a triangular slip rate function is not correct, since you are applying multi time-window approach?

We’re confused as to what is meant here. The rise time of each triangle is fixed to 5s for the M7.8 and 3s for the M7.6. An example sketch is below, note the rise time (width) of each triangle is constant (red dashed lines). We do not invert for the rise time of each triangle but rather for their amplitudes. In other words, the triangles are basis functions to invert for a more complex slip rate function



31. Line 204: "..slip on one of five time ..." Is it one or more of five time-windows?

It's five time windows, our wording was confusing please see the changes made.

32. Line 219: "elogated activity"? Is it "spatially elongated or temporally elongated ..."

Spatial, modified for clarity.

33. Line 223: "the Ekinozu earthquake ..."

Modified as requested

34. Line 249: "muted slip".. Perhaps "tapered slip"

Modified as requested

35. Line 259-260: Perhaps, what you want to say is: "The ground motions recorded at the stations ...."

Modified as requested

36. "Animation S1" - "Animation S1 in the supplementary data ".

Modified as requested

37. Figure 4 (also in Figure 6) captions - instead of "Inset numbers", "Labelled numbers"

Modified as requested

38. Line 295-298: Does that mean your inference/observation of super-shear ruptures has uncertainty with possibility of being otherwise, due to choice of inversion Parameters?

Some uncertainty exists yes. That's what the Vrmax curves in Fig 2C reflect. However, the RMS curve for the western rupture of the Mw7.6 is flat towards higher speeds not towards lower speeds. So, the data allows for even faster ruptures. Once you move in the sub-shear direction misfit increases significantly. So, our argument is that even if there is uncertainty about the true value of Vrmax, that a super-shear velocity is required seems robust.

Reviewer B : Ezgi Karasozen (for the Turkish abstract only)

Thanks for submitting a Turkish abstract. Please revise the text to make sure it is consistent with the English summary:

- Earthquake relocations of the first 11 days should be mentioned.
- Findings for both events' nucleation and rupture patterns should be summarized.
- Maximum rupture speed and direction for the Mw 7.6 event should be 4.8 km/sec and westward.

Modified as requested

Reviewer C : Ahmed Elbanna (for the Arabic abstract only), attached file

The reviewer provided a new Arabic translation of the English abstract (attached). He wrote:

“The original Arabic version of the abstract misrepresented many concepts. I tried to stick to the content as much as possible and only added a few connecting words for the flow.”

If you want to thank Reviewer C for his translation (what I would suggest), he also added: “I have no problem in identifying my name with the disclaimer that I do not endorse the validity of the technical content of the paper.”

Can you provide the translated text to include into the text?

Comments from the editor:

- l 121: “and slips bilaterally”

Modified as requested

- l 159: “for the success of the modeling”

Modified as requested

- l.160: “follows: we”

We don't think a colon is appropriate here

- l. 163. “a small mapped surface rupture”: do you mean in the InSAR data? Or previously mapped? Please clarify.

Modified to: "… mapped surface rupture from remote sensing data (Reitman et al., 2023)"

- l. 165: replace "necessitates it" by something like "further suggests its presence"

Modified as requested

- l. 177: replace "using a finite element meshes into" by "with"

Modified as requested

- l. 177: replace "this results" by "resulting"

Modified as requested

- l. 181: reference for orbits?

Added

- l. 227: add a point before additionally

Modified as requested

- l. 229: "that do assume this fault"

Modified as requested

- l. 300: "no obvious super-shear rupture in the first event": It would be interesting to mention/discuss this preprint: doi.org/10.31223/X5W95G

Added reference and brief discussion at that line

- l .302: low RMS: refer to Fig 2c

Modified as requested

Additional Figures / information:

1) Please provide a map with the name of the stations (shown in Figs 4 and 6) printed, either in supplement or by modifying Fig 1.

2) You probably have those figures ready: please provide figures (in supplement) for the data fits of the cases you mention in l. 236 (first scenario for rupture on the EAF, you mistakenly refer to Figs 3 and 4) and l. 302 (one example with higher vmax for the 7.8 event).

Figures and captions have been added to zenodo, they are pasted here for easier review. We also added relevant call outs to these figures in the text.

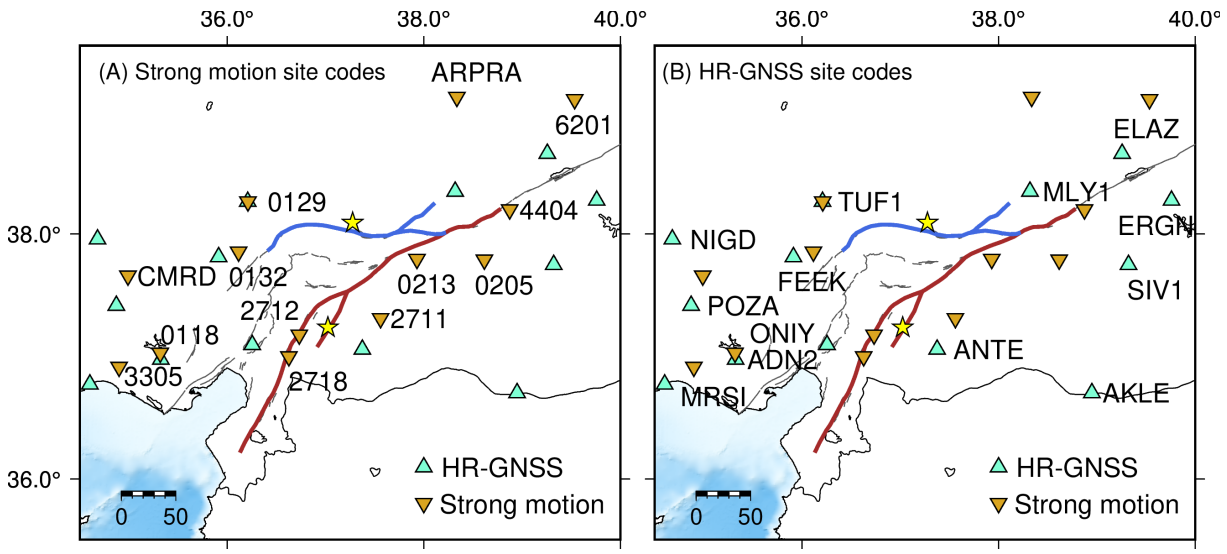


Figure S1, station code names (A) Strong motion and (B) HR-GNSS. Fault traces are the same as in Figure 1.

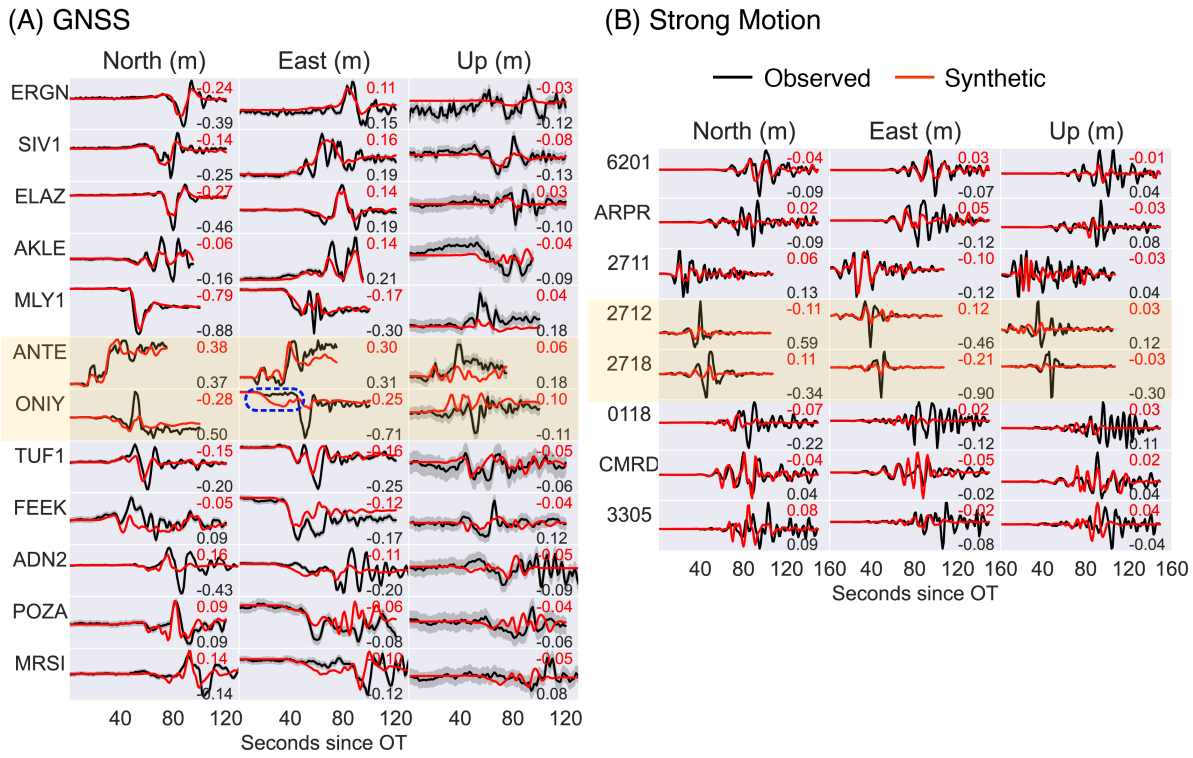


Figure S2. Waveform fits for the *Mw* 7.8 event when considering rupture on the EAFZ triggering at the time of the arrival of S-waves from the hypocenter. Compare to Figure 4 for reference to the delayed triggering of the EAFZ. Notice how stations close to the hypocenter (HR-GNSS stations ANTE, ONIY, and strong motion stations 2712, 2718, locations in Figure S1) have particularly poor fits. This is most obvious in the east component of ONIY highlighted in the dashed blue line. Here the initial phase of ground motion in the synthetic (red) is much larger than in the observed (black) hinting at the need for delaying slip until rupture from the Nurdağı-Pazarcık fault reaches the EAFZ as in Animation S1.

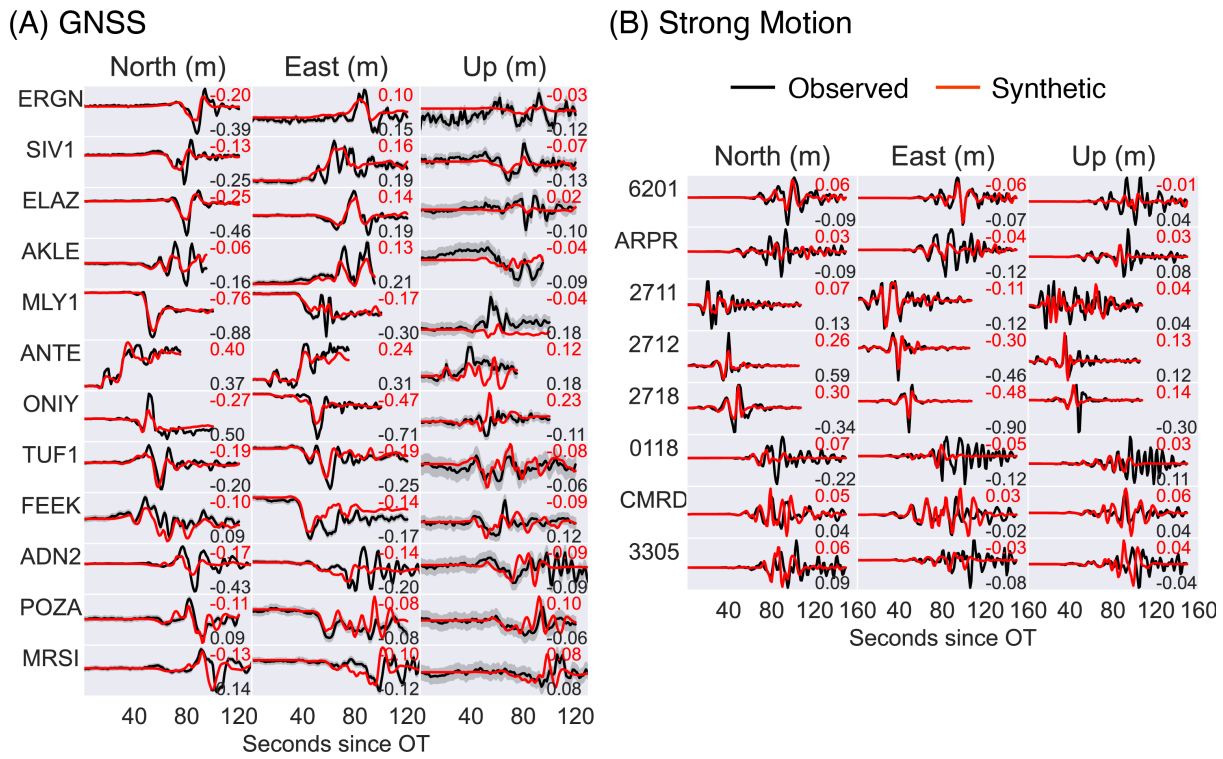


Figure S3. Same as Figure 4 but considering a maximum rupture speed of 3.8 km/s instead of 3.2 km/s. This would be equivalent to a super-shear rupture.