1 Editor in Chief

I have some minor comments.

The first and last sentence in the abstract are long and heard to read. I suggest to break them into short sentences.

Done.

Line 36: delete “magnitude”

OK.

Line 47: delete “Interesteingly”

Corrected.

Line 53-54: usually strike-slip earthquakes do not generate tsunami. Maybe add a one sentence to explain this?

Sentence added.

Line 120: maybe change “episodic” to campaign? Usually we don’t say episodic GPS.

Changed throughout the text, though both terms are actually used in the GPS literature.

Line 143: ”eat west”?

Corrected.

Line 326-328: Long and difficult to follow. Maybe break it into two sentences?

Corrected.

Line 355: delete ”vast” and maybe try to quantify this statement in terms of percentage?

Done.

2 Reviewer #1

Supershear rupture is a key focus in the study of earthquake source kinematics and dynamics, as its discovery and understanding can deepen insights into earthquake rupture mechanics while also highlighting its potential to cause more severe seismic hazards. This manuscript titled “The 28 January 2020, Mw7.7, Cayman Trough / Oriente Fault, Supershear Earthquake Rupture” utilizes back-projection imaging and joint inversions of teleseismic, regional broadband, strong-motion, and GPS data to examine a more detailed rupture characteristics of the 2020 Mw 7.7 Cayman earthquake. The study reveals subshear to supershear rupture transition features during the predominantly westward propagation, and discusses possible mechanisms behind this phenomenon. Below, I present some general comments and minor suggestions based on my review of the manuscript:

General comments:

Accurately identifying supershear rupture can be quite challenging for ruptures that are spatially and temporally close to the initiation point, especially for the rupture velocity very close to the shear wave velocity. Additionally, relatively sparse observations can further complicate the analysis. Consequently, I have some reservations about whether the rupture in the FLVR1 part in this study should be classified as supershear, for the following reasons:

(1) In the resolution tests for finite fault inversion, the slope corresponding to this segment (Figure 5 in Supplements) seems to be slightly larger than the theoretical value of 4 km/s. However, in the inversion based on observations, the slope is closer to 4 km/s (Figure 5 in the Main text), which could suggest that the actual rupture velocity might be somewhat lower than 4 km/s;

(2) The results from the back-projection imaging in this study along with those from Bao et al. (2022, Fig. 3a), and Cao and Ge (2021, Fig. 7), seem to collectively suggest that the rupture velocity before 40 s is more in line with subshear rather than supershear;

(3) The FLVR1 segment corresponds to an inner part of the biggest asperity, while it's not a common or widely observed phenomenon that a rupture transitioning from sub-shear to supershear in an asperity;

Given these points, I would suggest that the authors consider testing a subshear velocity for this segment in the resolution test. Comparing the results with the current supershear interpretation might offer a clearer and more intuitive understanding of the potential differences, and provide readers with a better sense of the associated uncertainties.

Following the reviewer's suggestion, we conducted a new synthetic test using an input model where the rupture velocity is subshear along the FLVR1 segment of the real data inversion. The resulting figure is now added to the supplementary material. In response to the reviewer's comments, we have added the following text to the manuscript at the end of section 3.2.4 "Resolution test":

"To assess whether the near 4 km/s rupture velocity along the FLVR1 segment may be overestimated by the inversion procedure, we conducted an additional synthetic test using an input model in which the rupture velocity is subshear along that segment. The result is presented in supplementary figure 6), in which panels (e) and (f) show that the inverted rupture times along the aforementioned segment remain close to, or even slightly lower than, the average 3 km/s reference line. However, points within that particular segment tend to align in a way that suggests a rupture speed that locally exceeds 3 km/s, i.e., larger than the input synthetic value. This means that the local slope of about 4 km/s along the FLVR1 segment in the real data inversion should be considered with caution. We conclude that the rupture speed along the FLVR1 segment is within the range of 3.5 to 4 km/s, possibly supershear but with some uncertainty."

Specific details:

1. Line 29-33: The authors have discussed many factors, such as stress level, fault geometry, and the locking depth. They are all related to the generation of supershear rupture. While just two aspects are mentioned here in the abstract. I am curious about how the authors consider the effect of the pre-stress level?

Right, as indicated in the conclusion, we consider that the earthquake rupture corresponds to "the accumulation of a large amount of elastic energy over a long fault segment during the interseismic time interval". We added a brief statement referring to this in the abstract.

2. Line 35: Please uniform the capitalization of "Figure" throughout the manuscript.

Done.

3. Between Line 125-126: I am confused with the "128" in the figure caption?

Corrected.

4. Line 148: xxx Yucatan (∼4mm, site xxx) $->$ sites

Corrected.

5. Between Line 251-252: Additionally, please ensure that the numbering of subfigures is consistent throughout the manuscript.

Done.

6. Line 415-428: This part mentions that the supershear rupture of this earthquake occurred in the "positive" direction of the bimaterial fault interface, which is uncommon. The difference in material velocities on either side of the fault is also an important factor to consider. I would suggest providing an estimate of the velocity contrast between the two sides to help readers better assess the potential impact of this factor.

The limited tomography results available in the study area show crustal wave speeds on the order of 3–3.5 km/s for island arc rocks of the Cayman Rise (Gonzalez et al., 2012) and similar values for the oceanic crust of the Cayman Trough (Grevemeyer et al., 2018). However, one cannot comment on the implications of these numbers because there is a lack of proposed relations between the level of material contrast and the occurrence of supershear ruptures in the positive direction. This knowledge gap is described in the review of theoretical, numerical and experimental results on this topic by Shlomai et al. (JGR 2020, "Supershear Frictional Ruptures Along Bimaterial Interfaces"). We now cite this reference in the manuscript.

Based on the points raised above, I would suggest a minor to moderate revision of the manuscript. This would help to address the issues discussed and further strengthen the overall analysis.

References:

Bao, H., L. Xu, L. Meng, J.-P. Ampuero, L. Gao, and H. Zhang, 2022, Global frequency of oceanic and continental supershear earthquakes, Nat. Geosci., 15, no. 11, 942–949, doi: 10.1038/s41561-022-01055-5.

Cao, B., and Z. Ge, 2021, 2020 MW7.7 Caribbean Sea earthquake: A supershear event revealed by teleseismic P wave back-projection method, Chinese Journal of Geophysics (in Chinese), 64, no. 5, 1558–1568, doi: 10.6038/cjg2021O0214.

3 Reviewer #2

This manuscript presents a comprehensive investigation of the 28 January 2020 Mw 7.7 strike-slip earthquake on the Oriente transform fault. The authors jointly invert local, regional, and teleseismic waveforms with GPS-derived coseismic offsets to produce a high-resolution finite-fault slip model that captures evidence of supershear rupture occurrence and the transition from subshear to supershear speeds. Complementary high-frequency imaging via slowness-enhanced back-projection on both the Alaska and European seismic arrays confirms the timing and location of this transition. The authors also offer a different perspective on why the rupture reached supershear speeds: a century-long seismic quiescence and an unusually shallow interseismic locking depth, both of which favor large elastic-energy accumulation and reduced fracture-energy barriers. Overall, this work provides a robust and systematic analysis and further explores extreme earthquake behaviors. I have a few comments below, it will be great if the authors could address them:

Commments

(1) The supplementary figure 2, 3 is not clearly visible, please change it to high-resolution figures.

Done.

Questions

(1) Line 240 - Line 243: the authors attribute the small slip patch in the lower eastern corner of the finite-fault model to an artifact of the chosen fault geometry and inversion smoothing. It will be better if author could provide justification for this conclusion: whether alternative fault geometries or smoothing weights could eliminate the patch or other publications exist the similar artifacts due to parameter choice?

We acknowledge that the justification was not clear and that mentioning a smoothing effect was not appropriate. The argument about the fault geometry is related to the fact that east of the epicenter, the fault system becomes less simple, with multiple branches, as one approaches the Cabo Cruz pull-apart basin. Since we tried to model the rupture with a single fault plane, it is possible that the small slip patch in the lower eastern corner is an attempt of the inversion to account for some slip occurring on a secondary fault branch. This is also supported by this small patch has an inconsistent rake (less than -45). We therefore modified the manuscript as follows:

"The small patch observed in the lower eastern corner of the model should not be considered reliable, as the fault system becomes geometrically more complex east of the epicenter, with multiple branches, as one approaches the Cabo Cruz pull-apart basin. Since we model the rupture with a single fault plane, it is possible that this small slip patch is a biased attempt of the inversion to account for slip occurring on a secondary fault branch."

(2) The author explains in details about the North/East components of stations LCCY and FSCY were interchanged and their amplitudes halved before inclusion in the joint inversion, and were down-weighted by a factor of ten. Could authors explain the possible effects of the stations: What inversion results do you obtain if LCCY and FSCY are omitted altogether? How much do key rupture parameters (e.g., maximum slip, average rupture speed, total seismic moment) change when their weights are varied within a reasonable range?

To address the reviewer's question, we performed two additional inversions, one with a weight of zero for stations LCCY and FSCY (stations omitted altogether), the other with an intermediate weight of 0.05. The results are illustrated by two additional figures and a table, which we added to the supplementary material. We added the following text to the manuscript, at the end of section 3.2.3:

"To test the sensitivity of the results to stations FSCY and LCCY, we performed two additional inversions, one with a weight of zero for those stations and the other with an intermediate weight of 0.05. The results, presented in supplementary figures 7 and 8 and supplementary table 8, are stable in terms of slip distribution and rupture timing. As one should expect, the waveform fit at those stations worsens as the weight decreases, particularly for a weight of zero. We observe a slight dependence of the maximum slip and average rupture velocity, which, respectively, increase and decrease as the weight is decreased. In any case, the main conclusions of this work remain valid when the FSCY and LCCY stations are omitted or their weight is varied in the inversion."

(3) Although the authors conclude that the rupture maintains supershear speed once it transitions, the finite-fault model clearly shows a "slip gap" (SG) separating two supershear patches. Please discuss possible physical mechanisms by which the rupture could re-nucleate and re-accelerate into a second supershear episode beyond this gap?

The reviewer raises a fair point. We accounted for it by adding the following text to the revised manuscript:

One interpretation consistent with a slip gap is the mechanism known as "barrier-induced supershear" found in numerical simulations (Dunham et al., 2003; Dunham, 2007; Liu and Lapusta, 2008; Lapusta and Liu, 2009; Weng et al., 2015) In this mechanism, a rupture arrests on a barrier and transfers stresses to the fault segment beyond the barrier; the resulting higher stresses there favor re-nucleation and supershear rupture. Alternatively, noting that the finite source inversion model shows low-amplitude slip below the slip gap, it is possible that back-projection images a deep, continuous part of the rupture that radiates sufficiently at high frequencies despite its small (low–frequency) slip. In fact, high- and low-frequency slip have been observed to occupy different areas of the rupture in the 2011 Tohoku earthquake (Meng et al. GRL 2011) and other large events (Lay et al, JGR 2012).

Given that both quiescence and shallow locking depth vary spatially, how do the authors compare their relative contributions and argue which was the dominant control on achieving supershear speeds?

We accounted for the reviewer's comment by adding the following text to the revised manuscript:

Both quiescence and shallow locking are observed in the rupture area, but not in the unbroken fault segment east of the mainshock. This suggests (speculatively) that large earthquakes on the eastern segment would be less likely to go supershear. However, we cannot determine which of the two factors, quiescence or shallow locking, would be dominant.

(4) Line 321 - Line 322: The author shows the results that the high-frequency sources have an apparent ∼10 s stationarity at the western termination of the rupture before radiation ceases, could the author elaborate how robust is this feature to variations in back-projection parameters? any possible connections with the slip patch determined in the finite fault model? what physical interpretations of this pause?

We decided to remove this sentence from the revised manuscript for two reasons. First, these apparently stationary HF sources at the western end of the rupture are actually not that convincing a feature on the figure. Second, after further investigation of the back-projection, we concluded that this apparent feature is most likely the result of back-projection artifacts as one begins to image the coda – or scattering – from the rupture rather than the rupture itself.