Jeremy Rimando, Amy Williamson, Raul Benjamin Mendoza, Tiegan Hobbs:

We have reached a decision regarding your submission to Seismica, "Source Model and Characteristics of the 27 July 2022 MW 7.0 Northwestern Luzon Earthquake, Philippines".

Based on reviews received (reviewer A and my own comments on the paper), your manuscript may be suitable for publication after some revisions.

Sincerely,

Mathilde Radiguet

Handling editor comments:

In the paper the authors use InSAR data to constrain the fault geometry of the Mw 7 2022 Luzon earthquake. This is a simple, first order study were three possible fault geometry are investigated, and the discussion focussed on the possible fault system that could have hosted the rupture.
It does provide in my opinion valuable information that could be used in the future for more complex studies, including more data (either joint study with seismic data, addition of surface rupture constrain ect), and is thus suitable for publication as a Fast Report.
I agree with the reviewer's comments that the choice of the optimal fault planned considered could be better justified, and that additional details should be given on the selection of the inversion regularisation scheme.
Based on my own reading of the paper (see detailed comments below) and the reviewer's comment, I recommend publication once the comments have been taken into account.

Detailed comments:

Earthquake Source modeling: in this paragraph you could clarify how you select the 2 faults planes tested.
- l. 157: the focal mechanism (strike, dip, rake) for the USGS and PHIVOLCS models should be given (for USGS we have the information on Table 1 but not for PHIVOLC). Since they are used to constrain the 2 faults planes they should be given.
- did you investigate the optimal fault location around the surface fault trace in both cases ? It sounds like an easy thing to test.

- l. 251: it is surprising that you mention that the ARF model better reproduces the LOS displacement, since from Table 1 it has higher misfit compared to the VAF model (0.83 instead of 0.79). Could you comment on that ? Why do you prefer the ARF model ?
- From Fig. 3 high residuals in the VAF model are localised in a limited area on the North of the fault plane, whereas they are more distributed in the VAF model. Can you explain the origin on the localised high misfit in the VAF model ? is that why you prefer the ARF one ?

Figure 1:
- Show the location of the cross section shown in C on fig. 1B.
- In C, show the location of the VAF and ARF faults (at least the surface trace).
- the fault planes considered in the following could be shown also in the cross section, and aftershock location could be discuss as it is a constrain to select the optimal fault plane.
- use a difference police for fault's name and focal mechanisms name (USGS, PHIVOLCS)

Reviewer A:

This is a rather quick and simple case study that provides limited insights into the event. The authors use InSAR data to invert for the slip distribution model of the Mw 7.0 Luson earthquake that occurred two months ago. The focal mechanism solutions provided by the USGS and PHIVOLCS are used as the fault geometry parameters and the locations of the estimated fault are fixed to match the know fault traces. The optimal inversion results are determined by comparing the simulated and observed deformation in a least-square manner. The preferred model is located west of and parallel to the ARF and exhibits reverse slip characteristics, which accommodated by the

Philippine Fault zone, subduction zone and intervening minor faults. Why don't you use InSAR data as the constraint to invert for the fault geometry? The known seismogenic fault geometry may exist large deviation causing large misfits. The source parameters are normally correlated during the fault inversion process. It is important to evaluate the uncertainty of model parameters examine the accuracy of the inverted parameters. Please add the model uncertainty.

I have a couple of minor comments that are listed below.

1. L38, 13-16 km is not shallow.
2. Line151-153. How strong is the atmospheric noise? It would be helpful to show original interferograms, corresponding atmospheric map and the corrected interferograms in the same colorscale.
3. Line 149-150. "A coherence mask with a threshold of 0.085 was applied to the data prior to unwrapping with the SNAPHU algorithm". This threshold is set too low. Why do you choose such a small threshold?
4. Line 192. "The inversion result was constrained using a Tikhonov spatial regularization scheme. Our resulting models (Fig. 3A and B) minimize the data misfit without overfitting, or allowing for too 'rough' of a final solution.". Please describe the method in detail and provide the intermediate results, such as the L-curve.
5. Line 251, but the VAF model shows the lowest misfit. The VAF is a left-lateral strike slip fault, what the authors selected it as the potential fault given that the focal mechanism of the 2022 event is primarily thrust?

Recommendation: Revisions Required

Response to Reviewers for: Source Model and Characteristics of the 27 July 2022 M_W 7.0 Northwestern Luzon Earthquake, Philippines by Rimando et al.

Below we have compiled our responses to Reviewer A and the handling editor. All of our responses below are marked in blue, we, when possible, left the format of the review comments as is. We thank the reviewers for their thoughtful comments, which we believe have strengthened our manuscript.

Handling editor comments:

In the paper the authors use InSAR data to constrain the fault geometry of the Mw 7 2022 Luzon earthquake. This is a simple, first order study were three possible fault geometry are investigated, and the discussion focussed on the possible fault system that could have hosted the rupture.

It does provide in my opinion valuable information that could be used in the future for more complex studies, including more data (either joint study with seismic data, addition of surface rupture constrain ect), and is thus suitable for publication as a Fast Report.

I agree with the reviewer's comments that the choice of the optimal fault planned considered could be better justified, and that additional details should be given on the selection of the inversion regularisation scheme.

Based on my own reading of the paper (see detailed comments below) and the reviewer's comment, I recommend publication once the comments have been taken into account.

Response: The authors would like to thank the editor, Dr. Radiguet, and the anonymous reviewer for taking time to evaluate our paper and for providing valuable comments and constructive feedback. We have addressed all of the comments and made the necessary changes in the manuscript as described below.

Detailed comments:

Earthquake Source modeling: in this paragraph you could clarify how you select the 2 faults planes tested.

Response: We selected two test fault planes in addition to a forward modeling of the USGS fault plane solution. The first tested fault plane has a fault trace and orientation that aligns with the documented Vigan-Aggao Fault (indicated and labeled on Figure 1B, the trace of our test fault is shown in Figure 3(a,d,&g). The second fault plane tested aligns generally with the Abra River Fault (ARF). This is the fault plane that PHIVOLCSs suggests as a probable candidate for rupture. However, as you may have noted in Figure 3, our fault trace is ~5km west of the current fault trace from the ARF. We guide our exact fault trace location partially by the line of sight displacement pattern recovered through InSAR. Moving the fault plane to the west aligns better with the observed data (as opposed to bisecting the main region of deformation). Additionally, the exact trace of the ARF in this area is uncertain and often updated with the addition of new seismic data so we feel comfortable exploring this fault plane and its orientation in this study. Other faults local to this area such as the Naglibacan Fault and Bangui Fault (both in Figure 1b) are not optimally oriented for the USGS/PHIVOLCS focal mechanism and therefore were not explored as potential fault planes. In order to address some of the confusion, we have expanded our earthquake source modeling section (lines 165-169) to better explain why we used these two fault planes and excluded other local faults.

- l. 157: the focal mechanism (strike, dip, rake) for the USGS and PHIVOLCS models should be given (for USGS we have the information on Table 1 but not for PHIVOLC). Since they are used to constrain the 2 faults planes they should be given.

Response: Thank you for bringing this up, we have added information about the focal mechanisms from both the USGS and PHIVOLCS to our introduction section in paragraph 1 (lines 63-65), where we introduce the event.

- did you investigate the optimal fault location around the surface fault trace in both cases ? It sounds like an easy thing to test.

Response: Thank you for this question. As mentioned in Section 1, there has so far been no surface rupture identified by the PHIVOLCS team on the ground. Therefore, we cannot compare our modelled faults to an observed surface rupture. In case this comment refers instead to the projection of the modelled fault planes to the surface, we have added text to lines 244-246 to reflect this.

- l. 251: it is surprising that you mention that the ARF model better reproduces the LOS displacement, since from Table 1 it has higher misfit compared to the VAF model (0.83 instead of 0.79). Could you comment on that ? Why do you prefer the ARF model ?

Response: The model misfit between the VAF and ARF fault models is quite similar. We did note that the ARF model had a better fit close to the earthquake source than the VAF model, which tipped the scale in favor of the ARF model.

- From Fig. 3 high residuals in the VAF model are localised in a limited area on the North of the fault plane, whereas they are more distributed in the VAF model. Can you explain the origin on the localised high misfit in the VAF model ? is that why you prefer the ARF one ?

Response: A small amount of slip in the VAF model towards the top of the fault appears to have an outsized effect on the misfit for the northern area above the fault plane. While this is an artifact, it is difficult to remove without over-smoothing our fault model.

Figure 1: Show the location of the cross section shown in C on fig. 1B.

Response: The cross section in (C) shows all seismicity from (B), mapped by longitude (E-W). Therefore, there is no cross section line. However, we have added additional text to the caption to make this clearer (lines 106-108).

- In C, show the location of the VAF and ARF faults (at least the surface trace).

Response: We have modified figure 1C to indicate the locations of the surface traces of the VAF and ARF with black inverse triangles.

- the fault planes considered in the following could be shown also in the cross section, and aftershock location could be discuss as it is a constrain to select the optimal fault plane.

Response: We have indicated the location of the surface traces of the VAF and ARF. However, given the distribution of aftershocks, we do not think that the seismicity itself provides constraints to determining the optimal fault plane among the fault planes examined in this study, and so plotting the modelled fault planes here would not be so useful.

- use a difference police for fault's name and focal mechanisms name (USGS, PHIVOLCS)

Response: We have adjusted the font for the focal mechanisms' names; we used a white font with a black outline instead to distinguish these from the fault labels.

Reviewer A:

This is a rather quick and simple case study that provides limited insights into the event. The authors use InSAR data to invert for the slip distribution model of the Mw 7.0 Luson earthquake that occurred two months ago. The focal mechanism solutions provided by the USGS and PHIVOLCS are used as the fault geometry parameters and the locations of the estimated fault are fixed to match the know fault traces. The optimal inversion results are determined by comparing the simulated and observed deformation in a least-square manner. The preferred model is located west of and parallel to the ARF and exhibits reverse slip characteristics, which accommodated by the Philippine Fault zone, subduction zone and intervening minor faults. Why don't you use InSAR data as the constraint to invert for the fault geometry? The known seismogenic fault geometry may exist large deviation causing large misfits. The source parameters are normally correlated during the fault inversion process. It is important to evaluate the uncertainty of model parameters examine the accuracy of the inverted parameters. Please add the model uncertainty.

Response: We thank the anonymous reviewer for a thorough revision and their helpful questions. Specifically relating to the optimal fault geometry, we found that with the limited time to prepare *Seismica Fast Reports* we had to maintain a fairly narrow scope. Therefore this study does not purport to assess the optimal fault geometry. We still believe that this first attempt is useful in displaying the predicted slip for two fault planes selected based on expert judgement of the area. We have added text to line 169 to reflect this. In addition, we now include our checkerboard tests in the supplement. These tests can generally show where we can and cannot resolve fault slip. Broadly speaking for this project, there is enough data to resolve slip at shallow depth, but some smearing of the checkers, or loss of resolution along dip as the depth increases. While some of the slip from this event occurs close to this lower resolution zone, we still believe that we reasonably resolve this area for the scale that we are interested in.

I have a couple of minor comments that are listed below.

L38, 13-16 km is not shallow.

Response: We have adjusted the text accordingly to omit the word "shallow".

Line151-153. How strong is the atmospheric noise? It would be helpful to show original interferograms, corresponding atmospheric map and the corrected interferograms in the same colorscale.

Response: The mean atmospheric noise value is -3.48 radians with a standard deviation of 2.51. A diagram showing the original and corrected interferograms, as well as the atmospheric map, has been added to the supplementary material as Fig. S9.

Line 149-150. "A coherence mask with a threshold of 0.085 was applied to the data prior to unwrapping with the SNAPHU algorithm". This threshold is set too low. Why do you choose such a small threshold?

Response: The low coherence threshold was chosen to retain a sufficiently large number of data points for phase unwrapping. We have found that increasing the threshold to 0.1 results in a similar deformation pattern and values, while increasing the threshold to 0.15 or higher greatly reduces the number of points available for unwrapping.

Line 192. "The inversion result was constrained using a Tikhonov spatial regularization scheme. Our resulting models (Fig. 3A and B) minimize the data misfit without overfitting, or allowing for too 'rough' of a final solution.". Please describe the method in detail and provide the intermediate results, such as the L-curve.

Response: We have elaborated further in our description of the Tikhonov regularization in our methods section (lines 209-214). Tikhonov regularization is a damped least squares method for regularizing inverse problems. In this case, the same amount of smoothing is applied to all subfaults in our model through use of a scalar multiple. As this value approaches zero (less and less smoothing), the problem approaches a non-regularized least-squares solution. We have also included our L-curves for both fault inversions in the supplement.

Line 251, but the VAF model shows the lowest misfit. The VAF is a left-lateral strike slip fault, what the authors selected it as the potential fault given that the focal mechanism of the 2022 event is primarily thrust?

Response: Thank you for this comment. We have adjusted the text on lines 277-280 to reflect the fact that both the ARF-parallel and VAF planes have similar L2 misfit. We have also added text to lines 173-174 to address the potential issue of using a sinistral fault as a possible source fault for a thrust rupture.