

To the Editorial Board of *Solid Earth*

Dear Editor and Reviewers:

5 First of all, we would like to express our sincere gratitude for the huge amount of work that was done by both reviewers. We very much appreciate their careful consideration of our manuscript. The comments were rigorous, but very constructive and friendly. Not only were the recommendations and advice useful for us in the context of the present work, but such comments will also be valuable for our future papers.

10 We have considered very carefully all the comments of the reviewers, and for the vast majority of the comments, we have made corresponding corrections in the manuscript. Among the most important changes, we can single out the following revisions:

- 15
1. We have considerably changed the structure of the main sections in the paper and reformatted the text correspondingly.
 2. We have added a test with synthetic Moho.
 3. We have added Fig. 3 with travel times versus distance.
 4. In Fig. 2, we have added a plot showing the general distribution of all stations of the ENSN.

20 All the changes are described in detail in the attached response letter.

We hope that you will find our paper improved and suitable for further consideration in *Solid Earth*.

Sincerely yours,

25

Sami El Khrepy, on behalf of the coauthors

30 Response letter for the paper by El Khrepy et al. “Seismic structure beneath the Gulf of Aqaba and adjacent areas based on the tomographic inversion of regional earthquake data”

The author’s responses are highlighted with violet and indicated with “REP”

35 Anonymous Referee #2

General Comments:

40 The reviewed paper shows the results of the tomographic inversion of P- and S-wave travel times in the Gulf of Aqaba. I really think that the results presented in this manuscript are very interesting, providing new valuable information to understand the structure beneath the Gulf of Aqaba and the geodynamics implications derived from that. For this reason I think that this manuscript is clearly within the scope of SE. Nevertheless, the present manuscript needs of major revisions to be suitable of being published in this journal. First of all the manuscript has a problem of organization because is not following the standard structure of a scientific paper. The different sections do not contain what it should be expected.

45 REP: The text and organizational structure of the paper have been considerably reformatted (see other replies).

A clear example is the Introduction that it is a mixing of Introduction, general knowledge and geological setting.

REP: We agree with this comment and separated the Introduction text from the Geological setting text.

50 But sections such as the Results or the Discussion are also very confusing and they need a hard work to make them suitable for publication.

REP: The Results and Discussion sections have also been reformatted considerably in response to all the reviewers’ comments.

55 Another issue to considerer (in some point it is related with the organization problems) is to clearly state which is the main purpose of the presented work. This is really important because this is the reason why the authors are written the paper. Obviously, if it is clear the paper is easier to organize. In any case, all these issues will be addressed in more detail in the Specific comments.

60 In spite of these general comments I really encourage to the authors to work in this manuscript because I think that the results contained on it are a significant contribution of the knowledge of the study area.

65 Abstract: this part of the manuscript needs to be rewritten. The abstract should include the purpose of the investigation (at the beginning), the methods used, the major findings and finally a brief summary of the interpretations and the conclusions. In my opinion, in this abstract the purpose of the work is not clear (only a description of the area is done), and the interpretation and conclusion (a brief summary) are missing.

REP: The abstract has rewritten according to these recommendations.

Introduction:

70 This part of the paper is really confusing and needs a hard work. An introduction should content three main parts: i) a general context of the problem that will be addressed in the paper including a summary of the existing knowledge and the current

situation. ii) state the purpose of the work and iii) a brief explanation of your approach and what you can obtain from it to provide a solution to the problem. This is not accomplished at all in the Introduction of this manuscript.

75 REP: In the annotated version of the manuscript, we have indicated subtitles (red font) according to the plan proposed by the reviewer. These subtitles can be removed from the main manuscript before publication.

The first problem is that the Introduction includes a mixing of Geological Setting and Introduction that should be fixed. Move all the significant (important according to the problem presented in the manuscript) geology that helps to understand the study area to a new section. This will make a huge difference that it will help the reader to follow the manuscript.

80 REP: According to this recommendation, a new section titled “Geological setting” has been created.

After moving the geology to a new section the Introduction should have more fluency. The structure should move from general information and focusing down to the specific problem the authors studied. For example, the first paragraph of the Introduction (L23-L34) is an example of that. It is just a description of several features: seismicity, evidences of tectonic processes because of the bathymetry and sedimentation rates. How are they related to the problem described in the manuscript? What is it relevant for your study?

85 REP: We tried to reorganize the Introduction in response to this advice. We hope we understood the reviewer’s comments correctly.

90 Another important thing observed in the Introduction is to clearly point out who is the author of the statements presented there. For example (between L70-L74), in the description of the Fig. 2 several statements are done: “left-lateral displacement and the rotation”. Where is this information coming from? Garfunkel, 1981 or Eyal et al, 1981? Or is coming from other source?

95 REP: We have added here “According to our reconstruction...” (L329–331). So, we make the reconstruction to achieve the best fit of the main basins along the DST, and then compare it with estimates made by other authors.

This fact is also observed between L76-L81 talking about the pull-apart mechanism. Which is the source used? The bibliographic quotes should be located in the right place to support the statements done in the Introduction. (NOTE: remember that this a comment about the Introduction but probably this paragraph should be in Geological Setting if this is considered for the authors).

100 REP: We have indicated the appropriate references for the pull-apart mechanism (L103-104) and (L336).

The last paragraph in the Introduction is the first place where the authors clearly states why they are doing all this work. Basically it consists of filling the gap between the crustal and upper mantle studies. This should be clear from the beginning (Abstract and Introduction) and it is not.

105 REP: The Abstract and Introduction have been revised.

Geological Setting:

All the information regarding to the geological context, regional and local, should be moved to this new section.

110 REP: We did this in accordance to the reviewer’s recommendation.

Data and Algorithm:

This section is pretty fine but several issues should be addressed:

115

L122-L124: The authors state that the events coming from different catalogues were merged into one catalogue list. Is this a direct merging or is there any data quality control? If I correctly understand the authors are using existing arrival times and they don't carry out new picking.

REP: We already used picked data from the catalogs.

120

So I don't know if the confidence of the travel times coming from different catalogues should be taken into account. I think that more information about that should be included. Are both catalogues using different stations? Why are the authors giving priority to ENSN for the same event?

REP: We mostly used events located within the ENSN network because they had better location parameters than those provided by the ISC.

125

Are the stations presented in Fig. 3 from ENSN, ISC or both? A few sentences explaining that should be necessary.

REP: We have added a few sentences specifying the procedure for merging the ENSN and ISC data (L115–118). In Fig. 2, we have added a plot with the regional data distribution and depicted the ENSN and ISC stations with different colors.

130

A figure including example of the data and the quality of the picks used in the inversion could be interesting. In the manuscript the authors describe that the low magnitude of the earthquakes used and the sparse seismic network used provided a limited number of picks for every event. This is a good reason to show examples of the data to demonstrate their quality.

REP: In this study, we absolutely did not touch any waveform data and only used the catalog data picked by others. Therefore, it is hard to present any example for picking. Unfortunately, we could not address this reviewer's comment.

135

L124-131: In this part of the section, the authors explain the data base used in this manuscript. It seems that the same data set used in the Gulf of Suez study is the one used in this work. They claim that only 53 (of almost 300 stations) are located in the area of interest but it seems that they used other stations outside the area during the inversion. This is clear in Fig. 4 where the ray paths are plotted. Taking into account that it will be great to see all the stations used in this study that maybe can help to understand why they were used. A figure including all the stations and the study area will be much better. (REP: The new Fig. 2 provides this information.) The other question is to understand what "marginal effects" really means. Do you need better azimuthal coverage for event location? Including stations out of the study area allow you to use seismic events with less than 6 picks? This part needs more information. (REP: We have added a sentence addressing these questions in L126–127.)

145

L137-139: To remove the outliers, the authors use absolute residuals of 1.5 and 2.0 seconds. Is it a standard criterion established/used elsewhere? If it is not, could you explain a little bit more why you are using these values?

REP: We have added a sentence addressing these questions in L120–121.

150

Table 1: This table is really confusing. Most of the parameters are not relevant and difficult to understand their meaning and how significant are those values for the inversion. Keep the relevant values.

REP: We have removed a few lines that described non-relevant parameters.

155

L165-174: The selection of the initial 1D P-wave velocity model and the Vp/Vs ratio is not clear. Several questions should be addressed in this part of the manuscript. The choice of an appropriate initial model is pretty important to obtain the right relocation of the events and obviously the best final 3D velocity model. Reading the text is unclear which criterion is used to build the initial model and the Vp/Vs ratio. (REP: The main criteria used were the minimum number of rejected picks and

160 minimum average residual deviation.) The authors state that they used a trial method to find the best initial method. How are they building these models? (REP: In each case, we changed the values of the Vp/Vs ratio and P-velocity at one or several depths and then performed the location analysis of events in this model. Furthermore, we made several trials of full iterative tomographic inversion to be sure that the best model provides a balanced amount of positive and negative anomalies at all depths.) Are they using previous information? (REP: No a priori information was used.) How many initial models are used? (REP: ~20; L163.) How do the authors modify the different models tested?

165 REP: We have changed the description for the optimization of the 1D model and addressed all the reviewer's questions (L160–170).

170 Furthermore, looking at the final velocity models and the variability of the crustal thickness it seems to me that the use of only 1D model for all the area can condition all the results. Is it possible to build more sophisticated initial models (2D for example) to account for lateral crustal thickness variation? Is it possible to estimate the robustness of the final model in relation to the chosen initial model?

175 REP: If we had a robust trustworthy crustal model for the entire region, it would make sense to use it as a 3D starting velocity model. In our case, not much information on the Moho depth is known. Any predefinition of the 3D velocity structure would affect the results. Thus, it would be not easy to distinguish whether the structures we observed were due to the predefined model, or whether these were really actual structures.

180 Table 2: Is this table necessary? Maybe a figure showing all the initial models used and the chosen one, including the parameters that reveal this model as the best one, will give more information about the initial model building.

185 REP: In our opinion, numerical values in tables are more relevant than graphs on a figure, as they can be directly used by other scientists in their calculations. Therefore, we prefer keeping this table in the paper. However, if the editor insists, we can easily construct the requested figure.

Results:

185 This section also needs a new organization. The checkerboard tests could be included in a separated section, something like Resolution tests. Two figures of the paper are dedicated to synthetic tests so probably a section should be necessary.

REP: According to this comment, we have created a separate subsection titled "Resolution tests".

Several comments about the checkerboard tests:

190 Which is the unperturbed velocity model used to create the synthetic travel times? Is the tomographic inversion using the same initial 1D model and Vp/Vs ratio? I guess so.

195 REP: We have added the following two sentences to address this question: "The synthetic anomalies have been added to the reference 1D velocity model with constant Vp/Vs ratios. In this specific case, this reference model is presumed to be known" (L185–186).

About the horizontal resolution test I have several comments. First of all, this is a results section so what we expect is a more detailed description of the obtained images. For the horizontal sections only one sentence (L195-197) is used to explain the checkerboard tests. You need a more description of what you see in the sections. Did you try other size cells? If 50x50 km is the smaller one that it is offering a nice result? Which is the implication of that in the anomalies interpretation? What is

200 happening at 50 km? I guess that at this depth you are not retrieving the data so this is the reason you are presenting only sections from 10 to 40 km.

REP: We have added a paragraph that considers all these issues (L187–193).

205 Use that to introduce the explanation of the results observed at different depths and remove the sentence “The reconstruction of this model is presented at four depths level”. This should be a sentence for the figure caption.

REP: This sentence has been removed from the text and added to the figure caption.

The same comments can be applied for the vertical resolution tests. Most of the paragraph is used to explain how the checkerboard tests are created and plotted and only a few sentences to explain the results and their implications over the results.

210 REP: We have added several phrases describing the vertical resolution in different parts of the study area (L201–205).

Furthermore, in L202-205, the explanation of the vertical resolution tests is pretty unclear. The text: “The presented results were obtained from the reconstruction of 4th sections were defined” is very confusing. This part should be rewritten to clearly understand what the authors exactly did.

215 REP: These sentences have been completely rewritten (L197–199).

Moving to the description of the travel time inversion, several issues need to be addressed: The description of the Results is very poor and probably some of the information in Discussion should be here. In this section you should describe objectively your key results in a logical sequence, without interpretation and supporting your comments with the figures. The Results section should show the evidences needed to answer the questions that you are trying to investigate in this work and they will be interpreted in the Discussion section. This is not done in this section.

220 REP: We have added a large block of the text containing a description of the main patterns that we observed in the resulting figures (L235–256).

225 The authors should introduce how they are presenting the results and why they are presenting in this way (anomaly maps, absolute values, the vertical sections, the colour scale used to make easy the correlation with geological features, etc.).

REP: We have added a comment regarding the development of the color scale for absolute velocities (L253–256).

230 In this description the information should appear in a coherent sequence and not just a sequence of sentences without any connection that are basically a description of a figure (should be in figure caption) or sentence pointing out what is plotted in a figure. An example of that is the text from L220-228. The figures are complements to understand what the authors are explaining in the text.

REP: We have considerably updated the text. The description of the results now follows a coherent progression from the shallower to deeper sections.

235 After that the authors should describe the results observed. They should prepare the reader for the interpretation and discussion. It is important to point out what is relevant in the results but from an objective point of view. This should be the Results section. This is not achieved in this manuscript. For example, in the paragraph between L220-224 the authors describe how they plot the figure (much of this information could be in the figure caption) and nothing is explained about the Fig. 7. What do we see in this figure? (REP: See the above comments.) Why are you not plotting this figure in absolute values? (REP: In figures with absolute velocities, we also provide one horizontal section with absolute velocities; see Figs. 9 and 10.) You need to describe the main features that they will give you the support in the Discussion section.

240

245 In this section is very important to support the text with a figure quote. For example, if the authors are talking about one figure it should be easy for the reader to know which figure they are referring to. The question is make easy to the reader to follow the description of the Results.

REP: We have added more references to the figures within the text.

250 L236-240: The last paragraph is unnecessary. The authors should talk about the similarities and differences of two velocity models and what they mean related to the objectives proposed in this work. If the results are presented in a manuscript it means that objective parameters related to the inversion are assuring the quality of the final models (convergence, checkerboard tests, ...). They cannot use this argument (at least not in the paper) as a robustness test of the model.

255 REP: In our opinion, stating the correlation between the P- and S-anomalies is an important message that should be presented in the paper. Personally for us, if structures in P- and S-velocities are completely different, this looks very suspicious. In nature, at least on a regional scale, P- and S-anomalies usually behave similarly (e.g., the slab is always “blue” and the plume is “red”). If P- and S-structures are different, this should be a reason for special checking and discussion. The discussion on this issue is important to us. We have moved the relevant text up and removed the last sentence about verification (L232–234).

260 Discussion:

The Discussion is a complete mess. Obviously the lack of a good description of the Results makes really difficult to build a logical sequence in the interpretation and discussion of the results. The authors should use the Results section to show the main features observed in the velocity models, focusing in those that are relevant to address their objectives. (REP: In the new version of the paper, all relevant features has been described in the Results section.) When all the features are well described to the reader they should give an interpretation of all of them according to the objectives described in the Introduction. (REP: In the Introduction (L34–43), we have added information for several key questions that were considered based on our results in the Discussion section.) That means that every relevant feature observed need to be explained, if it’s possible (if not it has also to be explained) providing a general picture of the study area to derive geological, geodynamic or tectonic implications.

270 Furthermore these implications need to be based in facts or at least an hypothesis that can be supported by other authors or similar works. For example, in L261-264 petrophysical hypothesis are proposed but any explanation for that is given. Any reference to seismic velocities expected for these petrologies (at this depths and geological context) or reference to other works in similar geodynamic context.

275 REP: We have added a reference to a review paper that describes typical values for seismic velocities in the felsic and mafic crust; that paper was authored by Rudnick and Fountain (1995).

The Discussion needs to be rewritten.

REP: We have considerably reformatted the Discussion section and added subheadings to improve the organizational structure.

280 In addition, the discussion of the results need to be clearly supported by the figures. In most of the Discussion the references to the figures are completely missing. There are plenty of reference to the horizontal sections, vertical sections, absolute velocity, 30 km section, but the figure number is not there. In this way, it is impossible to follow the Discussion and objectively appreciate the implications of the results presented in this paper to the knowledge of the study area.

285 REP: We have included references to the figures in many places within the Discussion.

Conclusion:

290 In my opinion, Conclusion section contains a lot of information that should be in Discussion. It is the only section in the manuscript that finally provide to the reader of a clear description of the objectives and how this work is trying to provide solutions to them. The authors should follow this to reorganize the paper.

Technical corrections:

295 L93: Author name is different in the reference list and the text. It should be Ginzburg if I'm not wrong. In this line is written Ginsburg.

REP: Corrected. Thank you.

L76: Add the reference to which plot: "In this plot" (Fig. 2) or use "In Fig. 2" instead of. The text must be clear to the reader.

300 REP: Corrected as recommended.

L112: In the Abstract and Data and Algorithm section two different sources for the data set used in the manuscript are meant: ENSN and ISC. In this line only the first one is used

REP: Corrected. Thank you.

305 L118: Change "from seismicity" and use, for example, "seismic events"

REP: This has been changed to "earthquakes".

L142-143: Add bibliographic references about other tomographic studies using LOTOS code

310 REP: We have added a reference to the web site where all the user manuals and source codes are stored. Just adding some other tomography studies not related to this story seemed inappropriate to us.

L150-151: Remove this sentence: "The distribution of the parametrization nodes, together ...". This is the description of the figure and it is located in the figure caption. Within the text, the reference to a figure is just to support the text. It is not necessary to include a sentence describing the figure.

315 REP: This sentence has been rewritten.

L161-162: Remove the sentence: "Values of the main parameters used..." for the same reason that the previous comment.

REP: In our opinion, this short sentence is necessary as it introduces Table 1. The sentence was therefore retained.

320 L215: Which is the value of the picking accuracy reported by ENSN? If you know the value it will be great to compare with the residuals reduction.

REP: We have added the estimates for the picking accuracy, i.e., 0.1–0.15 s for the P-phases and 0.15–0.2 s for the S-phases (L222–224).

325 L220-224: This paragraph should be rewritten and included in a more exhaustive description of how the velocity are plotted and why they are plotted in this way. The paragraph, in the way is written, seems more a figure caption than a Results description.

REP: The relevant text containing the description of the results has been completely rewritten.

330 L225-228: This should be written together with the description of how the velocity models are presented in this manuscript. If the authors are using this colour scale in order to make easy the correlation with geological features you should clearly explain that.

REP: A more detailed explanation on the development and use of this color scale has been added to the Results (L253–256) and Discussion (L282–285).

335

L243-244: Again, do not present what is in the figure. Talk about the horizontal sections and support that with the reference to Fig. 7. The same for the other figures.

REP: We tried to avoid repeating the information in the text and figure captions throughout the manuscript.

340 Figures:

Something observed in most of the maps is the lack of a scale (distance). I know that the maps are geographically referenced but it could help.

345

REP: We have created kilometer distance scales for all maps where there were no other kilometer scale indicators (i.e., such as locations of the profiles).

Figure 1. The authors refer to this figure talking about the depths reached for the Gulf Aqaba sea floor. If this information is relevant and they are using the colors to identify different depths in the figure, a color scale should be included.

REP: A color scale for the bathymetry is presented in Fig. 1.

350

Figure 3. I referred to this figure early in my comments. In my opinion all the stations used in the inversion should be included with a label (different icon used of color) for the different Institutions instruments. The study area should be indicated within this more general location map. A legend indicating this information will be also useful.

355

REP: We have added a large-scale map that includes stations from the ENSN catalog and those from the ISC catalog, and these different types of stations are represented with different colors (Fig. 2); a small-scale map related to the study area was also included.

Figure 6. The orientation of the profiles should be included in both corners of every section. We don't have a location map for them so we need to know how they are oriented.

360

REP: Actually, the km marks indicated in the map exactly correspond to the distance scale in the vertical section. This gives us an unambiguous reference.

Figure 8 and 9. The same for this figure. The orientation of the sections should be also in the sections.

365

Figure 10. Legend for the structural features presented in this figure.

REP: We have added a description for the red dotted lines (dykes). The other symbols were already explained.