Author Response to RC2 (Awad Bilal)

Major comments responses

[1] While reviewing the manuscript, there have been some instances where the scientific approach was either oversimplified or need further clarifications. For example,

[1a] The authors attributed uncertainty in fault and horizon interpretations to mainly image quality. However, it was not clear to me what does seismic quality means in the manuscript (i.e. low amplitude and homogenous reflectors? low amplitude, chaotic reflectors? or noisy seismic. etc.). In addition, there was no information about the seismic data in the materials and methods section. I appreciate the work done in section 3.3 (seismic data quality) but I worry about the use of RMS attribute (reflector strength) to assess seismic data quality. Strong seismic reflections do not necessary means high seismic quality. Clear definition of what the authors consider as high or poor seismic quality is therefore crucial.

I suggest the authors start by describing the seismic stratigraphy of the sequences and the seismic characteristics of the analysed Top Ness horizon. Areas of poor seismic quality can then be highlighted together with the possible reasons behind low quality data (e.g. depositional environment, inherited low quality i.e. processing. . . etc). In order to give the reader more confidence, I suggest including a new figure (as Fig. 2 or 3), comprising two, N-S and E-W seismic sections, showing the interpreted horizons and seismic quality.

AUTHORS RESPONSE: Thank you for pointing out the lack of definition of the term seismic data quality. We have added a paragraph to the manuscript to explain our definition of the term. As our manuscript is mainly concerned with a first-look statistical description of the uncertainties encountered in 3-D seismic interpretation, we think it out of scope of this work to do a detailed study on the sources of seismic data quality and how it affects interpretation uncertainty. Nevertheless, this would be a logical next step for future research.

CHANGE IN MANUSCRIPT: Throughout this work we make use of the term seismic data quality not in the strictly geophysical sense of quality factors surrounding seismic data acquisition and processing, but rather in the sense of the interpretability of the seismic data. If the seismic data lacks clear, continuous reflectors in a region, but shows a noisy image difficult to interpret – no matter what the source of this may be – we describe it as an area of low seismic data quality. Similarly, if reflector strengths are high and continuous (for horizon interpretation) or clearly offset (for fault interpretation), we speak of high seismic data quality.

[1b] The authors observed that uncertainties in the horizon (Top Ness; Fig. 8) interpretation are significantly reduced surrounding wells with a general trend of increasing uncertainties from west to east. I suggest that this is further analysed and discussed. Important aspects to be considered are; (1) what is the seismic characteristics of the interpreted horizon? (2) what is the structural configuration (faulted, non-faulted) of the horizon; (3) how confident the students/authors are with both formation tops and well locations; and (4) is there any uncertainty in formation tops that can be compared/correlated to the uncertainties analysed in this paper. Additional factors that might also have affected interpretation include the level of assistance to students, time spent in the interpretation, the methodology and order of interpretation and how familiar the students were with using Petrel.

The fact that uncertainty increases away from well location is a general statement and, in many cases, it is invalid unless other factors are considered. Horizon interpretation uncertainty away from well location largely depends on the continuity of the horizon (also dependent on the depositional environment) and structural complexities. There are many cases where uncertainty is significantly low for hundreds of kilometres away from well location. Other cases show high uncertainty in near to the well or even in the Formation tops of the well.

AUTHORS RESPONSE: We have expanded our discussion regarding the horizon uncertainty surrounding well tops and faults in the results section to address some of the seismic characteristics of the horizon we believe relevant to the patterns (1). We believe the structural configuration is sufficiently characterized in the manuscript (2).

(3) We have no information about the inherent uncertainty in the formation tops and well locations.

(4) We have no information about the inherent uncertainty in the welltops. As all students received the same welltops, thus our analysis can be seen as "anchored" on the uncertainty in the dataset they received.

You raise a very good point regarding that the horizon interpretation uncertainty away from wells depends on the continuity of the horizon. We have incorporated this aspect into our manuscript.

CHANGE IN MANUSCRIPT: Figure 8a shows the average Top Ness horizon basemap for all interpretations combined. Overall the horizon interpretations are increasing in depth from SE towards the NW of the domain. Figure 8b shows the associated standard deviation of the average Ness horizon interpretation, with an overlay of mean fault intersections and well locations. We observe large horizon uncertainties in vicinity to both Faults 1 and 2 throughout the dataset. An increase of horizon uncertainty is poignant at the southern end of the domain where Faults 1 and 2 are beginning to merge again. In the North the horizon uncertainty surrounding Fault 3 decreases rapidly with distance from the fault, with two welltops and packages of high reflector strength (see Fig. 9A) constraining the uncertainty. As the seismic data quality decreases towards the south (see Fig. 9B), the uncertainty in the horizon interpretation increases in the Eastern part of the dataset. Interpretation uncertainties are significantly reduced surrounding well locations in the western part of the study domain, where seismic reflectors of the Top Ness horizon are overall stronger and more continuous (see Fig. 9A). This pattern does not hold true in the East of the dataset, where reflector continuity is overall low and noise in the seismic dataset is high.

[1c] I worry about the uncertainty of fault throw. For example, Figure 7b. shows that uncertainty is higher at smaller median throw (southern part of the fault), while it is expected to see high uncertainty at larger throw value. The figure also shows that same amount of median throw can have both high and low uncertainties (see central part of the fault Y 6784000). This can also be observed in Fig. 7a. Generally, uncertainty in throw mainly depends on the uncertainty of the correlation of the stratigraphic markers in the hanging wall and footwall blocks of the fault. For example, uncertainty in fault throw will be low where the stratigraphic correlation between fault blocks is good independently of throw value. In more detail, the uncertainty in cut-off angle in each sides of the fault depends on many aspects such as structural complexity, fault plane definition on the seismic, seismic quality near faults. The new publication of Ze and Alves titled 'Impacts of data sampling on the interpretation of normal fault propagation and segment linkage' might be of interest.

AUTHORS RESPONSE: We do not see problem of small median fault throws having larger uncertainties in this dataset. As we have described in the manuscript, the throw of Fault 3 becomes more uncertain towards the South. We have detailed the decrease in data quality from North to South, making both fault placement (shown in Fig 3A) and horizon placement (shown in Fig 7b) more uncertain, which explains how the uncertainty of fault throw also increases in this area. The lack of clear stratigraphic markers on both sides of Fault 3 in the South, and the existence of good stratigraphic markers in the North emphasize this (as seen in Fig 8A and B).

CHANGE IN MANUSCRIPT: -

[2] I believe that the manuscript would be greatly improved and give more confidence to the reader if the 'Key findings' section of the discussion part is discussed in more depth. The fact that uncertainty in seismic interpretation increases in areas of poor seismic quality and linkage zones is relatively well known and expected. I appreciate the work done on quantifying these uncertainties, but I advise that the results of the paper are discussed in more detail. One important aspect that could be highlighted is the reasoning behind the variability in seismic interpretations, taking into consideration other factors that might affect seismic interpretation. Human bias in seismic interpretation and the expertise of the interpreters can also be addressed. It would also be interesting to see whether the result would change if the interpretation was carried out by experienced seismic interpreters using seismic filters to improve seismic quality together with various attributes (i.e. the effect of the level of experience). The authors can also analyse the effect of training (supervised top Cretaceous horizon interpretation) in reducing horizon interpretation uncertainty.

AUTHORS RESPONSE: We have overhauled the discussion / key findings part of our manuscript based on your and the other referees' comments.

Collecting and analysing extensive 3-D interpretations from experts would indeed form a great study but is definitely out of scope for this experiment. Also, we believe that the effect of training can not really be analysed from comparing the results presented in the manuscript with interpretations of the Top Cretaceous horizon, due to its stark contrast in structural simplicity and high reflector continuity compared to the Top Ness horizon throughout the dataset.

CHANGE IN MANUSCRIPT: Please see the revised manuscript or change-tracked manuscript for all the changes in the discussion.

[3] While reviewing the manuscript, there have been several instances where the description was not clear, or the authors use a great deal of qualitative language. I would prefer some quantifications of what few, major etc mean. These together with other minor corrections are highlighted in the attached original manuscript.

AUTHORS RESPONSE: Thank you for making us aware of this! We have removed the use of subjective language throughout the manuscript and have incorporated a large amount of your minor corrections.

CHANGE IN MANUSCRIPT: A multitude of changes throughout the manuscript. Please see the revised manuscript or the change-tracked manuscript.

[4] Conclusions: This paper describes a very important aspect of 3D seismic interpretation. However, a clear and concise summary with a clear link to the results and discussion would highlight the significance of the paper and results. Hence, I suggest the authors add a short summary or conclusions as bullet points with a clear take-home message.

AUTHORS RESPONSE: We have added a clear and concise conclusion to the manuscript.

CHANGE IN MANUSCRIPT: Please see the revised manuscript for the added conclusion section.

[5] Figures: Overall, the figures of the manuscript are clear and well-presented but please make sure of the resolution in the final printed version. Text size in some figures needs to be increased. Several figures have neither a scale bar nor north arrow. I also have suggested re-drafting and/or adding three new figures. Detailed comments on these new figures and on each figure are highlighted in the attached original manuscript.

AUTHORS RESPONSE: Thank you for pointing this out! We have increased text sizes and generally improved legibility of the figures throughout the manuscript. We have added scale bars and North arrows where applicable. We improved our Figures throughout the manuscript due to the reviewers input and merged the histogram and stereonet plots to improve the clarity for the reader. We decided against adding additional figures as we believe our improved Figures will adequately provide the reader with the relevant information and it would further bloat the manuscript. As our study mainly focuses on the structural uncertainties, we believe the example interpretation in combination with the average basemap and the seismic sections in the Figure 8 provide the reader with the context they need to follow the manuscript.

CHANGE IN MANUSCRIPT: Please the see the revised manuscript for changes in Figures.

Detailed comments responses

Abstract

Overall, it provides a clear summary but I believe it will be updated according to the reviewer's comments.

AUTHORS RESPONSE: We did not make changes to the summary, as the scientific content of the paper did not change.

CHANGE IN MANUSCRIPT: -

Introduction

Overall, the text is clear but I suggest the authors further clarify uncertainty in seismic interpretation and make it accessible to non-specialists. The authors could simply address that conceptual uncertainty mainly comes from human bias in seismic interpretation and depends on the expertise of the interpreter. Also, other types of uncertainties such as geophysical uncertainty, uncertainties related to formation tops and check-shot data could also be highlighted.

AUTHORS RESPONSE: We agree that a more specific description of what kind of uncertainty we are investigating (and how it related to "objective" uncertainty) would increase the clarity of the manuscript.

CHANGE IN MANUSCRIPT: Our work is thus concerned with quantifying the scope of uncertainties in seismic interpretation, which represents inevitably biased, human judgment under uncertainty (Tversky and Kahneman, 1974). This "subjective" uncertainty is in contrast to more "objective" uncertainty (Tannert et al., 2007; Bond, 2015) related to the geophysical acquisition of the data itself.

[L12] Please add the name of the 3D seismic survey

AUTHORS RESPONSE: We added the name and details of the 3-D seismic survey in the dataset section 2.1. Thanks for pointing that out!

CHANGE IN MANUSCRIPT: -

[L14] I would be more specific here. Seismic noise at depth? Near faults?

AUTHORS RESPONSE: We have expanded the specific description of seismic noise and referenced relevant Figure with seismic sections giving an example.

CHANGE IN MANUSCRIPT: The dataset depicts a comparatively simple geometry of planar domino-style normal faults, but the seismic dataset exhibits high amounts of noise, especially in its eastern half, and generally increasing with depth and in fault proximity (see Fig. 9).

[L19] The authors have shown a simple fault interpretation of Fossen and Hesthammer (1998) as a reference example. How about horizon interpretation? Do you have an interpreted horizon? Please find further comments on this below (i.e. Fig. 8).

AUTHORS RESPONSE: We use the fault interpretations from Fossen & Hesthammer (1998) as a conceptual reference interpretation – i.e. their fault network topology and the reported fault orientations – we do not have access to their unpublished interpretation. We clarified this in the manuscript.

CHANGE IN MANUSCRIPT: We use the interpretation of Fossen & Hesthammer (1998) as a reference expert example (in the sense of Macrae et al., 2016) to compare fault network topology and fault orientation uncertainty with the student interpretations.

2.1 – Gullfaks geology and seismic data

The paragraph lacks information about the 3D seismic data. Key information includes (1) the name of the 3D seismic survey; (2) acquisition year; (3) whether the data is originally in depth or time? and (4) key information about processing history as this will further clarify the seismic quality issue. I would also add the key tectonic phases evolution of the area (i.e. how many phases and ages).

AUTHORS RESPONSE: We agree that this information is of importance so assess sources of uncertainty within the seismic data itself. However, we have limited information on the dataset and its origin. We have added all relevant information that is available to us to the section.

We disagree on adding further detail on the tectonic evolution of the area into the paper and refer to the comprehensive description in published literature, as it would further bloat the manuscript.

CHANGE IN MANUSCRIPT: The 3-D seismic survey of the Gullfaks field, ST85R9211, was recorded in 1985 and reprocessed in 1992. It was recorded in time and converted to depth using TWT depth conversion and was migrated using a Prestack Kirchhoff migration

L30-33 – Please clarify the research focus area both here and in Figure (1). I also suggest clarifying the scale of the interpretation area. Could you also highlight that the overall structure of the area is very complex particularly in the accommodation zone and collapsed footwall structures in the horst complex zone, while the western dominosystem (research focus) is comparatively simple.

AUTHORS RESPONSE: We have clarified the difference in complexity of the structural domains and improved clarity of the scale of the interpretation area in Figure 1.

CHANGE IN MANUSCRIPT: The field consists of three structurally distinct domains: a structurally simple domino system in the western part, and the structurally more complex accommodation zone and Horst complex towards the east (see Figure 1c). Our study focuses on the structurally simpler western part of the domino system, where we investigate the uncertainty of the three faults F1-F3 and the fault blocks A-E depicted in Figure 1b.

P3_Figure 1 - Please increase text size particularly in Fig. 1a and the Formation names in Fig. 1c. The location of the 3D seismic is not clear. The schematic fault map (b) is oversimplified. Please show fault displacement (fault polygons) and dip direction. Fault polygons would greatly help the reader to understand linkage zones as well as major and minor faults. I wonder how Fault 1 was identified in the northern part where it merges with Fault 2. Please see further comments highlighted on the attached original manuscript.

AUTHORS RESPONSE: We have improved the clarity of Figure 1. We have simplified the schematic fault map (Fig 1b) on purpose, as it was adapted from a heave-map of a different horizon from Fossen & Hesthammer (1998). We have added dip direction markers to the plot to improve clarity. We have shaded the schematic faults to make fault identification easier for the reader.

CHANGE IN MANUSCRIPT: Changes to Figure 1.

2.2 – Interpretation dataset

Many questions came to my mind with respect to seismic stratigraphy. What are the seismic characteristics of the Top Ness horizon and why it was selected for analysis? Please add this key information to give greater confidence to the reader with respect to the results.

AUTHORS RESPONSE: Our study focuses on the quantification of structural seismic interpretation uncertainties and we believe that a detailed discussion of seismic stratigraphy is out of scope for this work. The Top Ness horizon was interpreted by the students as part of their seismic interpretation course, thus the selection of the horizon was out of our hands. We agree though, that this would be very interesting topic for future research.

CHANGE IN MANUSCRIPT: -

P3_L4 – Please show the location of the wells in Figure 1. How confident you are with well locations and Formation tops.

AUTHORS RESPONSE: We have no way to assess the uncertainty related to the well locations and formation tops. We agree that this information is vital to an ideal, uncertainty-integrated workflow, but our study also focuses on the “subjective” uncertainty produced by the interpretation. All students started out with the same set of well information.

CHANGE IN MANUSCRIPT: -

P3_L8 – Why did students use manual interpretation? how often seeded tracking and manual interpretation were used?

AUTHORS RESPONSE: Due to the amount of noise throughout the dataset, manual interpretation would be necessary in many parts of the cube. We have no precise information about the frequency of individual interpretation tools. Our information is from the course instructions the students were given, and by interviewing a few students about their interpretation process. We have clarified this in the manuscript.

CHANGE IN MANUSCRIPT: Afterwards the students started to independently interpret the Base Cretaceous Unconformity (BCU) and Top Ness horizon (which is part of the Brent group) around well locations, followed by connecting the horizon interpretation in-between wells. The students were instructed to mainly use guided auto-tracking, as well as occasional seeded tracking and manual interpretation where possible or necessary, depending on seismic data quality.

P3_L9 – Do you mean interpolated auto-tracked surfaces? Did students actually use gridding? I would be more specific

AUTHORS RESPONSE: We removed the reference "gridded" as it can cause confusion in this context. It referred to the regularly gridded surfaces Petrel creates from horizon picks.

CHANGE IN MANUSCRIPT: The students then interpolated surfaces from the horizon interpretations using Petrel's Make Surface function.

P4_L3 – Why the Top Ness horizon was selected for analysis. Why not BCU

AUTHORS RESPONSE: Due to work volume constraints in the course, students were instructed to only interpret the Top Ness horizon below the BCU. We chose to focus our analysis for this manuscript on the Top Ness horizon, due to its higher structural complexity compared to the BCU.

CHANGE IN MANUSCRIPT: -

P4_Figure 2 - Please increase figure and text size. Also show both North arrow and a

scale bar.

AUTHORS RESPONSE: We have increased the text size and added North arrow and scale bar to the figure

CHANGE IN MANUSCRIPT: Figure 2 changes.

2.3 – Data analysis

It was not clear to me the key steps of the analysis. I would suggest adding a diagram showing steps of the workflow applied as this would greatly help the reader in particularly non-specialists. Please see further minor comments highlighted on the attached original manuscript.

AUTHORS RESPONSE: We decided against the addition of a workflow diagram, as we used common data analysis approaches to analyse our data and it would further bloat the manuscript. We provide our custom Python functionality in an open-source code repository for readers interested in the exact implementation. We hope our manuscript changes made particular parts of the data analysis clearer to the reader.

CHANGE IN MANUSCRIPT: Please see the revised or change-tracked manuscript for the changes made to the data analysis section.

P5_L8 – I am not aware of RMSA. I am sure RMS only (without 'A') would be fine.

AUTHORS RESPONSE: We define RMSA as a shorthand for RMS Amplitude to use throughout the manuscript for brevity.

CHANGE IN MANUSCRIPT: -

P5_6 - Figures 3 & 4 – I would suggest merging these figures or having both of them in the same page to make it easy for the reader to follow. Please make sure of the quality of the figure in the final printed version of the paper.

AUTHORS RESPONSE: Thank you for the suggestion! We have merged the two figures into one to improve clarity for the reader. Both figures are vector files, any quality issues might be due to pdf compression done by Copernicus or caused by the pdf-reader software used.

CHANGE IN MANUSCRIPT: Merged Figure 3 and 4 into Figure 3.

P6_L2-3 – What do you mean by spread? Can you make this clear?

AUTHORS RESPONSE: Spread is used in its statistical meaning identical to scatter or dispersion.

CHANGE IN MANUSCRIPT: Changed spread to dispersion for clarity.

P7_L13-14 – Why F3 was omitted? If it was interpreted in a similar fashion, why does uncertainty increases southwards as shown in Figure 3c?

AUTHORS RESPONSE: In all but a single student interpretation F3 does not interact with F1 or F2 and was thus not drawn in the fault network diagrams of the five most common fault network topologies, as it never changed. The uncertainty of F3's position and orientation increases towards the south, without impacting fault network topology.

CHANGE IN MANUSCRIPT: -

P8_Figure 6 – Can you show students number in the Y-axis of Fig. 6a. Please add fault numbers (e.g. F1, F2) and dip direction in Fig. 6b. I was wondering how the authors differentiated between A and C and how fault 1 was defined in the northern part where it merges with fault 2 (Fig. 6b).

AUTHORS RESPONSE: We have added student numbers to the probability mass plot, as well as fault numbers. We think that dip directions would unnecessarily clutter the figure without adding critical information. We have added dip directions to the overview plot in Figure 1.

We differentiate A and C by the location of the fault stick placements in the dataset. North of the merging of Fault 1 and 2, the fault has been classified as belonging to the fault that terminates the other. E.g. if Fault 2 terminated at Fault 1, and Fault 1 continued northward, it was classified as Fault 1. We have enhanced the Figure schematics to improve clarity.

CHANGE IN MANUSCRIPT: Changes to Figure 6 (now Figure 5)

2.3 – Fault throw and horizon uncertainty

It was not clear to me whether the throw analysis was carried out along fault strike or a strike-parallel window.

What are the reasons behind selecting faults 1 and 3 (which was interpreted in a similar fashion and omitted in the previous section) for throw analysis?

AUTHORS RESPONSE: We have chosen to show the fault throw analysis for Faults 1 and 3 as the results of our analysis are reliable for them. The complex nature of Fault 2 and its subparts made it quite difficult for our algorithm to confidently analyse the fault throw. We are working on improving our algorithm for future work to apply it confidently to more complex faults. Another reason is, that Fault 2 and 3 are good examples of how fault throw uncertainty is changing across datasets.

CHANGE IN MANUSCRIPT: -

P9_Figure 7a. - How about uncertainty in the linkage zone? I think that the increase in uncertainty near survey edge is more likely related to the complex linkage zone to the south where faults 1, 2a and 2b merge as shown in Figure 1. It is well known that fault interaction can influence fault propagation and hence, displacement profiles. Do you think that the displacement profile shown in Fig. 7a would change if fault 2 was added to fault 1. It will be very interesting to see both faults.

AUTHORS RESPONSE: We have modified Figure 7 to represent the data as boxplots along fault strike, which much better visualizes the changes in fault throw and its uncertainty, especially in the linkage zone of F1 and F2. Thank you for pointing out the linkage zone to the south – we've added this to the results.

CHANGE IN MANUSCRIPT: Changes in Figure 7 and throughout the manuscript.

P9_Figure 7b. – As indicated in the general comments above, this figure shows higher uncertainty associated with small median throw. Also, same amount of median throw show both high and low uncertainty. Please make of the analysis. Please see further comments highlighted in the attached original manuscript.

AUTHORS RESPONSE: We have redrafted Figure 7 as boxplots to better visualize the fault throw data. Fault throw in the Southern part of Fault 3 does show lower median with higher uncertainty (IQR), which is not unrealistic. We speculate this to be due to the problematic seismic data quality (in terms of interpretability), thus the variation in where students put the fault and their Top Ness horizon is increased (as seen also in Figure 8 surrounding Fault 3).

CHANGE IN MANUSCRIPT: Please see the change-tracked manuscript for the full amount of changes surrounding fault throw.

P9_L4-9 - One key question came to my mind while reading the last paragraph of page 9 (description of Figure 8) is that where is the actual interpretation of the Top Ness Formation. I strongly suggest that the best interpreted horizon is added. so the reader can see the actual interpretation of both horizon and faults. It would be even better if it was interpreted by experienced seismic interpreter.

AUTHORS RESPONSE: We have to disagree with adding the best interpreted horizon, as we believe this is not very meaningful in this context. We have a large number of interpretations, and a priori no interpretation is necessarily better than any other as we lack knowledge of the real subsurface situation. This is why we present the mean Top Ness horizon in Figure 8a: to visualize a single interpretation in combination with the uncertainty in Figure 8b.

CHANGE IN MANUSCRIPT: -

P10_Figure 8 – Please redraft to include (a) the actual (best) interpreted horizon, (b) average horizon, and (c) the standard deviation horizon. Also, please add north arrow and scale bar in all parts of the figure. Please see further comments highlighted in the attached original manuscript.

AUTHORS RESPONSE: Please see the above response in regards why we believe that adding a single best horizon is not meaningful in the context of this manuscript.

CHANGE IN MANUSCRIPT: Added scale bar and North arrow to Figure 8.

3.3 - Seismic data quality

As indicated in the general comments above. I worry about the title of this section as well as the framework and results. The strength of seismic reflector does not necessarily mean good seismic quality. I also worry about the use of a time slice (Fig. 9.1 & 9.2) to assess seismic quality based on the strength of a single seismic reflector as the results can be significantly different at different levels or even the same level.

AUTHORS RESPONSE: We have chosen the time slice because we believe it serves as a valuable example of how the uncertainty in the interpretation of a single fault can vary in response to the seismic data quality (in terms of structural interpretability). As RMSA attribute is calculated across a vertical window, it includes information about reflectors above and below the depth slice shown.

CHANGE IN MANUSCRIPT: -

I believe that interpretation of fault 3 was aided in the northern part of the fault (Fig. 9.1 & inline section A) because of both the sharp reflection termination and the good correlation between seismic reflection packages on both sides of the fault. Generally, fault interpretation dose not actually depends on individual reflections, instead packages of reflections across the fault.

AUTHORS RESPONSE: This is the conclusion we are reaching in our manuscript: that sharp seismic reflector termination (as indicated by the through in RMSA response in Fig. 9a) strongly decreases fault interpretation uncertainty. We use Fault 3 to show how interpretation uncertainty increases when the noise of the dataset decreases and how we can possible use the RMSA response as a proxy for uncertainty.

CHANGE IN MANUSCRIPT: -

I would suggest the authors further test their results and see if the same approach can be applied to Fault 1 and 2 where the high amplitude to the south (Fig. 9) coincide with high uncertainty in both fault (Fig. 3) and horizon (Fig. 8) interpretation. Moreover, the authors could test whether the results are same if (1) the time slice was replaced by RMS attribute extraction on the actually interpreted horizon; or (2) a different time slice (e.g. 2100 or 2300) was used. Further minor comments on this and Figure 9 are highlighted in the attached original manuscript.

AUTHORS RESPONSE: We chose to present our analysis on Fault 3 as it serves as a meaningful example of the impact of noise / data quality on the interpretation uncertainty of a simple fault without many fault interactions. Data quality is generally poorer surrounding Faults 1 and 2 (as also seen in the increased spread in Figure 3) and the structural complexity is higher (merging and splitting of the faults). This is why we chose Fault 3 as a simple first example because Faults 1 and 2 are much more complex. We agree that there is much more opportunity for further research on how structural complexity interacts with fault interpretation uncertainty and data quality and we are aiming to do further work on this in the future.

(1) is a very good point! In more complex cases extracting the RMSA along a horizon probe would be ideal. But we lack an "actually interpreted" horizon (or rather we have too many valid ones). We could of course use the mean or median horizon, but this is not necessarily meaningful. As the pattern of increasing noise from North to South holds true for the dataset at all depths surrounding Fault 3 we believe it to be adequate to use a depth slice instead of a horizon probe at an arbitrary interpretation.

(2) We chose this specific depth slice as it encompasses easily interpretable results in the North with deceasing interpretability towards the South to show the trend visualized in Fig. 9a-d on how interpretation uncertainty correlates with seismic data quality.

CHANGE IN MANUSCRIPT: Several changes in section 3.3, please see the revised manuscript or difference-tracked manuscript.

4 – Discussion

Please see the attached original manuscript for further minor comments on the discussion part.

AUTHORS RESPONSE: We have incorporated many of your minor comments into the manuscript.

CHANGE IN MANUSCRIPT: Please see the revised and change-tracked manuscript for a detailed overview of all changes made.