



JAMIE L. WHITTEN NATIONAL CENTER FOR PHYSICAL ACOUSTICS

June 20, 2021

RE: Topic Editor Decision: Publish subject to minor revisions (review by editor) (03 Jun 2021) by John M. Huthnance

Dear Dr. Huthnance,

Thank you for handling our manuscript.

We have followed your guideline to revise the manuscript. Our response to you and the reviewer's comments are attached below.

We hope you find our manuscript in a better shape and can support our work based on our improvement.

Sincerely,  
Zheguang Zou, Parsa Bakhtiari Rad, Leonardo Macelloni, and Likun Zhang  
The National Center for Physical Acoustics  
The University of Mississippi, University, MS 38677, USA



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Comments from Referee 3.

**Authors reply in bold.**

I am satisfied that the authors have addressed my previous comments. In particular, they have made efforts to shift the focus of this article toward physical oceanography whilst also clarifying the scope of this manuscript. The manuscript has been improved. There is room for further improvement by addressing a number of revisions listed below.

After reading the author's rebuttal and latest draft, I have three main comments. Each of my comments aims to help the authors to clarify the methods and/or significance of their work. These three main comments can be mostly addressed by implementing the specific comments listed below as well as the smaller comments in the attached pdf (N.B. I used Foxit Reader to make these annotations).

**Thank you for providing us these valuable comments which truly help us revise the manuscript and deliver a more clarified scope.**

Three Main Comments:

First, the authors could be even more explicit in some places where they describe their aims for this paper. After reading their rebuttal, I understand better their aims but would like more clarification closer to the start of the manuscript.

P.S. I'm looking forward to seeing the results of their next manuscript about internal wave variations in 3D.

**We have followed your comments to revise the paper to be more explicit in describing the aim in the abstract (Line 3-5) and in the Introduction (Lines 21-24, 68-72).**

Secondly, the implications of this paper are important for future 3D seismic oceanography studies. The questions laid out toward the end of Introduction are excellent "For example, how do temporal and spatial water-column variations distribute in a single 3D seismic volume? Can we quantify them? Is the oceanic 3D seismic imaging meaningful in all directions? The answers to these questions will be useful to guide the development of future 3D seismic oceanography."

However, the abstract does not answer these questions as directly as they have been laid out in the Introduction. I think that a slight re-wording of the abstract could clearly address these three questions and clarify the author's findings straight away.

**Thank you for recognizing the value of our paper for future 3D seismic oceanography studies. Now we have re-word the abstract to clarify our finding towards these questions (Lines 3-11).**

Thirdly, I appreciate what the authors aim to do with the theoretical and empirical analyses. I have several comments for this section that should help to clarify their analyses and strengthen their conclusions. Generally, the use of language has complicated this section. For example, "variation" is used in two different senses ("single-frequency variations" and "temporal and spatial variations"). The section would benefit from a careful re-read and strict use of specific terms.

Aside from the wording, there is room for improvement in the description of the analysis. For example, what equation is used to get the lines in Fig 8 a and b? I imagine that this will be obvious once explained. However, I am struggling to see how the temporal frequencies are plot on the x-axis of Fig 8 (i.e. in the spatial domain) with the current text.



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**Thank you for your comments and questions. We have followed your specific comments to improve the manuscript. We have used the term “single-frequency spatio-temporal variation” instead of “single-frequency variation” to reduce confusion.**

**For the description of the analysis, we have added the explanation, our calculation, and the equation that is used to plot Fig 8 a and b (Lines 241-259).**

**Hope you find our analysis is clearer now.**

Specific Comments:

Line 57: How about adding on some sentences here that bring it back to the oceanography. For example, "Seismic oceanography is the only method by which we can collect high-resolution, 3D information about the oceanic wavefield. At this early stage in the development of 3D seismic oceanography, understanding how temporal and spatial oceanic variability embeds itself in a seismic volume is critical to making the best use of this tool moving forward." These example sentences are a bit wordy, but hopefully you get what I mean.

**Thank you for your suggestion. We have implemented your edits in Line 21-24.**

Line 58. You use the term “embedded” a few times in the abstract and here. For example, “we explore temporal and spatial variations embedded in three-dimensional”. By “embedded” do you mean naturally recorded by the seismic acquisition system? Could you quickly define what you mean by embedded in this sentence? E.g. “we explore temporal and spatial variations embedded (i.e. variability that is predisposed to be recorded) in 3D ocean seismic volume”

**Your understanding is correct. We have defined the word “embedded” in Line 63.**

L64. As described by the authors in their rebuttal, the scope of their paper is to explore the potential of 3D seismic oceanography, and not focus on oceanographic insights. I think it would be good to add a sentence here, which explicitly sets the aims of the paper (and therefore the expectations of the reader). What about “We further conducted theoretical and empirical analyses to understand the distribution of temporal and spatial variations. Our principal aim is to explore how 3D seismic data record spatial and temporal variability of the ocean. In this contribution, we focus on the potential of 3D imaging, rather than interpreting these oceanic phenomena. This new understanding will be useful for the interpretation of 3D seismic data as spatio-temporal evolution of ocean interior structure, which is important to promote the development of 3D seismic oceanography”

**We have implemented your edits in Lines 68-72.**

L64--65. As far as I am aware, seismic oceanography is the only tool that can provide 3D information about the ocean. I think that is worth stressing here. How about rephrasing this sentence to: “We aim to promote the development of 3D seismic oceanography -- the only tool that can provide a full-depth, high-resolution, 3D data of the ocean -- and develop our understanding of how these data can be used to interpret the spatio-temporal evolution of ocean interior structure”

**We have revised this sentence to stress this in Lines 70-72.**

L80-109. In this section there is quite a lot of technical jargon. I suggest replacing technical terms with a laymen’s description and/or their objective. For example, “We have removed offsets greater than 4 km (half of the total channel number) to keep computational costs low, and to reduce the effect of long-offset deviations on the data preprocessing and velocity model building” could become “To reduce the effect of long-range noise and keep computational costs low, we use the portion of the dataset which



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has the greatest signal-to-noise ratio (i.e. data within 4 km of the acoustic source).” Another example, velocity analysis and normal moveout is used so that we can combine records that sample the same location. I have underlined what I mean by technical jargon with squiggly lines in the attached pdf.

**We have revised this part to reduce the usage of jargon (Lines 89-120).**

L109: Big mismatch between what and what? After reading your rebuttal, I would simply say that you used the CTDs to guide the velocity model development.

**We mean “between model and measure”. We used CTDs for quality control and benchmarking when there was a mismatch between model and measure as it is mentioned in Lines 106-115.**

L151. I am not sure what you mean by this first sentence and “relationship between time and space”. Can you expand/re-word? What about “After establishing the oceanic nature of seismic reflections, we now describe the distribution of the seismic volume in space and time”?

**We have revised the sentence as you suggested in Line 171-172.**

Title of Section 2.5. This title does not make much sense to me as you aren’t analyzing the survey lines here. What about “Survey Line Distribution in Space and Time”

**We have revised this subsection title.**

Line 291. “The visual, theoretical, and data-driven analysis of the 3D seismic volume...” Nice.

**Thanks.**

Line 308: What do you mean here “reflections within a large volume of subsurface are utilized and accounted for the out-of-plane acoustic scattering”?

**We meant 3D. We have rephrased the sentence in Lines 349-351.**

Line 319:” However, available data analysis methods, e.g. wavefield spectral analysis (Holbrook et al., 2013) and diffusivity estimations (Fortin et al., 2017; Dickinson et al., 2017), developed for 2D seismic oceanography can be safely extended to 3D inline images.” Can you explain this statement further?

Why does the temporal variation in inlines not affect these methods?

**We have explained this in Lines 360-362.**

Line 329: “Temporal variation being more prominent than spatial variation in the crossline direction is validated by the discontinuity in crossline images (Fig. 6), faster fluctuation in correlation function analysis in crossline direction (Fig. 9) and verified by theoretical analysis [Figs. 8 (b), (d)]”. This sentence is quite long and is difficult to read. Could you shorten it to clarify your meaning?

**We have revised this sentence in Lines 370-374.**

Paragraph at Line 348-361: A nice addition to your paper. I would re-order the sentences a bit, to bring your oceanic interpretation to the start, then the caveat at the end. Please also see some suggested edits in the annotated pdf. For example:

“Finally, based on our analyses of these 3D seismic images we can interpret the possible mesoscale ocean process occurring at the time of acquisition. Prior studies show the water dynamics in this region are dominated by Loop Currents and Mississippi river outflows, and possible ocean dynamics may include river plumes, internal waves, internal tides, and eddies (Coleman, 1988; Sturges and Lugo-Fernandez, 2005; Hamilton and Lee, 2005). According to our seismic images (Figs. 5–7), this mesoscale ocean process should have a



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temporal cycle longer than 8 days (the time separation between seismic images), a length scale larger than 25 km (exceeding the maximum width of our seismic images), and a depth of influence up to 600-800 m (down to the seafloor). Cross-referencing the above scales with the typical scales of possible ocean dynamics in this region, the only matched ocean dynamics are eddies. The Loop Currents create omnipresent cyclonic and anticyclonic eddies, moving northward and eastward in the Gulf of Mexico. We suggested that our seismic images have captured the process of an eddy approaching to the northern continental slope. When eddies approach the continental margin, they start to interact with the continental slope and generate internal wave fields over the slope. This process increases the vertical mixing and reduces the stratification, leading to a change of the water column from highly stratified to well-mixed (as seen in Fig. 5). A full investigation of the ocean dynamics observed by our seismic images, which would require further analysis of concurrent in-situ measurements and satellite data, is beyond the scope of this study, and will be conducted in our future study.

**Great suggestion. We have implemented your suggested order and other edits (Lines 405-419).**

Fig. 8. It would be helpful to plot panels a and b with the same y-limits. This change would make your interpretation of the figure easier.

**We have changed the y-limits of Fig. 8 a and b to be the same.**

Fig 9. Panels a and b could be transferred to Fig 8, as Fig 8 is where you first discuss these terms of inline and crossline variation.

**Thank you for your suggestion. However, we decide to keep Panels a and b in Fig. 9 as they are used to explain how to obtain variations along inline and crossline directions from an actual 3D seismic volume.**

Several Comments for Section 3.2 and 3.3:

Line 205-208: After reading your rebuttal, I understand what the aim is with your theoretical analysis. In order to set up the reader a bit better, these lines could be phrased slightly differently. Something like "This qualitative analysis of 3D seismic images (Figs. 5-7) reveals that temporal and spatial variations are embedded in the inline direction, whilst temporal variation is found mostly along the crossline direction. Next, we will conduct two analyses to quantitatively assess temporal and spatial variations within a 3D ocean seismic volume. We conduct a simple (i.e. single frequency) theoretical and complex (i.e. multifrequency) empirical analysis to quantitatively assess temporal and spatial variations within a 3D ocean seismic volume".

**Thank you for your suggestion. We have implemented your edits in Lines 228-232.**

L210-245. I think that this section would benefit from some clarification and more careful use of wording. In line 234, you say "in both directions", can you be more specific, e.g. in both the inline and crossline direction. In Line 214, you say "We use single-frequency variations". What do you mean by "variation"? My understanding is that you vary the frequency of the source from single to multi-frequency. Your meaning of variation needs to be clarified here. Furthermore, can you use a different word to "variation", as variation is also used for the temporal and spatial variation. Leading on from this comment....

**We have specified the "in both direction" in Line 270.**

**The term "single-frequency variations" means that the temporal or spatial variations (can be either temporal or spatial) have only one frequency component. Now we have revised it as "single-frequency spatio-temporal variation" to reduce the confusion.**



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Section 3.2 and 3.3 Titles:

Perhaps these titles could be more descriptive to help the reader. Quick ideas, “Spatio-Temporal Variation Associated with Single Frequency Sources” and “Spatio-Temporal Variation Associated with Multi-Frequency Sources”. I have italicized ‘sources’ regarding my point of confusion directly above. **Thank you for your suggestion. We have changed the titles to “Theoretical Analysis of Single-Frequency Spatio-Temporal Variations” and “Analysis of Variations in 3D Seismic Volume”.**

L220. Please can you include the equation that you use to estimate the lines in Fig 8 a and b. I can see that the spatial variation (blue line in Fig a and b) is one cycle per km. How are you plotting the temporal variation lines on the “Lateral distance” axes? This inclusion is essential to help the reader understand how you get from the experiment and variability settings to these lines.

**Thank you for your comments. The equation to generate lines in Fig. 8 a and b are now given in Line 251. When project the temporal variation to the space domain (i.e., lateral distance), the key is to figure out “how many temporal cycles have been covered in that distance?”. We have explained the calculation in Lines 239-259.**

Line 226. What do you mean by this sentence “Furthermore, we find that this conclusion can be extended to temporal and spatial variations for all ocean dynamics”?

**In the revised version, we have removed this sentence to avoid controversy.**

L229: “inline images mostly represent spatial variation of the water column, while the crossline images represent a combination of temporal and spatial variations of the water column.” Great sentence.

**Thank you.**

Line 248: “The results will provide empirical values in our seismic volume, which can also be useful to other seismic oceanography studies with similar setups”. Empirical values of what?

**We have changed the “empirical values” to “values of inline and crossline variations” Line 285.**

Equation 2: What are x and y exactly? The trace amplitudes? This sentence “ For 2D seismic images, x and y, the correlation is defined as:” needs to be clarified. I am not sure if x and y are the dimensions or the trace amplitude in the x and y direction.

**Your understanding is correct. We have now clarified this in Line 288.**

Line 251. It would be helpful to add an example here, which highlights that little variability = high correlation. For example, if that ocean was a volume of flat layers that extended in all directions with no variation over time, the correlation would be 1 for both temporal and inline.

**Great suggestion. We have added the example in Lines 291-293, and 300-302.**

Line 281. What are the spectra calculated from specifically? Can you give a Fig here? Generally, use of the word “variations” is confusing this paper.

**The spectra calculated from the black curves in Fig. 9. We have clarified this in Line 323.**



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Comments from Referee 2.

**Authors reply in bold.**

The authors revised the draft and improved it. It is good.

As I mentioned: "There are no obvious ocean features such as eddy, internal wave, front, staircases, etc observed in the seismic sections or slices. Physical oceanography implications are expected to be demonstrated after revision." So I hope there is some minor progress on interpretation of oceanic features in the figures and data.

Line 354-367: I do not think Line 354-367 is good enough. The interpretation based on Fig2, 5-7 can be more reasonable and professional. Maybe fine structure characteristics can be focused on, the authors can add a few sentences.

**Thank you for acknowledging the improvement of our manuscript.**

**In this revision, we have added a new paragraph dedicating to the interpretation of oceanic features in 3D seismic images (Lines 389-404).**