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Interactive comment on "Random Noise Attenuation of Sparker Seismic Oceanography Data with Machine Learning" *by* Hyunggu Jun et al.

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Thank you for your careful review and constructive comments. We have studied all of your comments carefully and revised our manuscript. We edited the English of the entire manuscript including "Abstract" by following Reviewer 2's recommendation.

This paper deals with the noise attenuation method of sparker SO data using machine learning. The data obtained from the sparker source have advantages such as cheap data acquisition costs and high vertical resolution from several centimeters to several meters, but it has not been widely used in SO study and has not been quantitatively analyzed to date. This is mainly because of the low S/N ratio of the sparker seismic data. Due to strong noise, the conventional data processing method is not sufficient to attenuate the noise in the sparker seismic data, thus it is difficult to perform quantitative analysis such as calculating slope spectrum. Therefore, we would like to propose a method to suppress random noise in the sparker seismic data. This paper tries to apply machine learning technology to remove random noise from sparker SO data to help interpret SO data, and confirm the possibility of quantitative analysis. Because of this reason, the machine learning methodology and application of the proposed method are the main part of the paper. After confirming the possibility of oceanographic analysis using denoised sparker SO data in this study, the detailed oceanographic analysis of East Sea data will be performed in the future study. Followings are the response to the Reviewer 2's comments.

Q1. line 34 - delete "relatively low" as you do not state relative to what. Please edit paper to remove, as much as is possible, unqualified comparative statements.

A1. We removed "relatively low" in line 34 and removed unqualified comparative statements in the manuscript.

Q2. line 46 - This problem is more accentuated in SO because the impedance contrasts between the layers are small.

A2. We modified the sentence.

Q3. line 65 - this reference list ignores the long history of the use of Neural Networks see McCormack's paper in Leading Edge 1991 which shows an early attempt to use these NN to identify noisy traces in seismic data, since then NN have been evaluated for many tasks in the processing of seismic reflection data. Suggest authors change sense to recognise the history but equally highlight the recent advances in AI. I now note that this history is partly addressed in the following paragraph.

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A3. We modified the sentence and added the history of Neural Network in seismic data processing.

Q4. line 153 - scaling by the sq-rt of time is not "spherical divergence" correction but a "geometric correction" as for true spherical divergence loss the amplitude scales by a 1/z which for a constant sound-speed medium is proportional to 1/t.

A4. We modified “spherical divergence correction” to “amplitude correction”.

Q5. line 158 - an SVD filter can be effective in removing direct wave and maybe worth trying, though extreme care is needed to get offsets correct and correctly estimate of surface mixed layer sound-speed

A5. To remove the direct wave, SVD filter or Tau-P domain filter would be appropriate. However, the source signature of the sparker data is more complex than that of the air gun data, thus the filter may not properly eliminate the direct wave. Moreover, the noise near the sea surface is severe and the section before 0.03 second is not our research target (interesting SO signal does not exist in that part because this part is mixed layer which does not have large differences in reflection coefficient), therefore we muted the section before 0.03 second.

Q6. Fig 3 - plot sections in the same orientation and spatially lined up so it is possible to appreciate the similarity/differences in the two images but note in caption or by arrow on section the acquisition direction.

A6. We plotted the sections in the same orientation and added an arrow indicating the ship direction.

Q7. line 183 - the subsurface will contain a range of reflection coefficients some will be

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tens to hundreds times larger but others will be of the order of magnitude as SO.

A7. We modified the sentence.

Q8. lines 220-224 - definition of epochs and iterations is not clear.

A8. We modified the sentence to clarify the definition of epoch and iteration.

Q9. General question about noise - it is not clear, or I have overlooked the statement in the paper, but was the noise section extracted from data before or after divergence correction? If so, have you not imposed a time scaling on the noise as environmental noise levels would be expected to remain constant with time? So should this denoising be applied to non-divergence corrected data?

A9-1. We extracted the noise from the processed seismic section which was applied the amplitude correction. Even though the background noise level is supposed to be not influenced by the time, the noise level at the early time in the East Sea SO data is larger than the deep part of the section (this might be the noise related to the complex source wavelet of sparker). Therefore, we empirically selected square root of time as scaling factor to make balance of the noise amplitude from shallow to deep part of the section.

A9-2. Since we extracted the noise from the amplitude corrected seismic section, we applied the trained model to the amplitude corrected seismic section to remove the random noise. If we extracted the noise from non-amplitude-corrected data, then we should apply the trained model to the non-amplitude-corrected data.

A9-3. Before calculating the data slope spectra, we scaled the seismic section again by multiplying square root of time to each time step (consequently multiplying time to each time step of the data) for the spherical divergence correction.

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Q10. line 290 - what is the "Static 94 synthetic seismic section?

A10. We modified the Static 94 to “velocity model of 1994 Amoco statics test dataset.”

Q11. Figs 16 17 see request for Fig 3.

A11. We modified the Figures.

Q12. A useful analysis would be to generate a synthetic with the expected spectral slopes then add noise at different levels and try to recover the input, the question I would like to know is is the shift after filtering (shown in Fig 19) removing weak signal too. Also discussion on the expected horizontal resolution. You state the peak frequency is 250 Hz which, after migration, should give a maximum horizontal resolution of âĹij1.5 m. However, it will be less as this is a 2D profile over a 3D structure so there will be out-of-plane contamination.

A12-1. We performed experiment using synthetic data.

A12-2. We also can find the shifting of the spectrum between the noise added synthetic section and noise attenuated seismic sections at the wavenumber smaller than 0.001 cpm. However, the difference is also observed between the spectrum of noise free section and noise added section. In addition, the shifting is not observed between the spectrum of noise free section and noise attenuated section. Therefore, this shifting seems to be caused by the characteristic of the noise extracted from the East Sea SO data.

A12-3. We also mentioned the shifting issue in the manuscript.

A12-4. In the conclusion, we added the limitation of 2D exploration related to the resolution. And we mentioned that it is necessary to acquire data by using 3D seismic exploration to improve the resolution

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