Convolutional Encoder Decoder Network for the Removal of Coherent Seismic Noise

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Background

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- Conduct seismic experiments where a wave is propagated through the subsurface
- Use this experiment to create images of the subsurface

Velocity Model

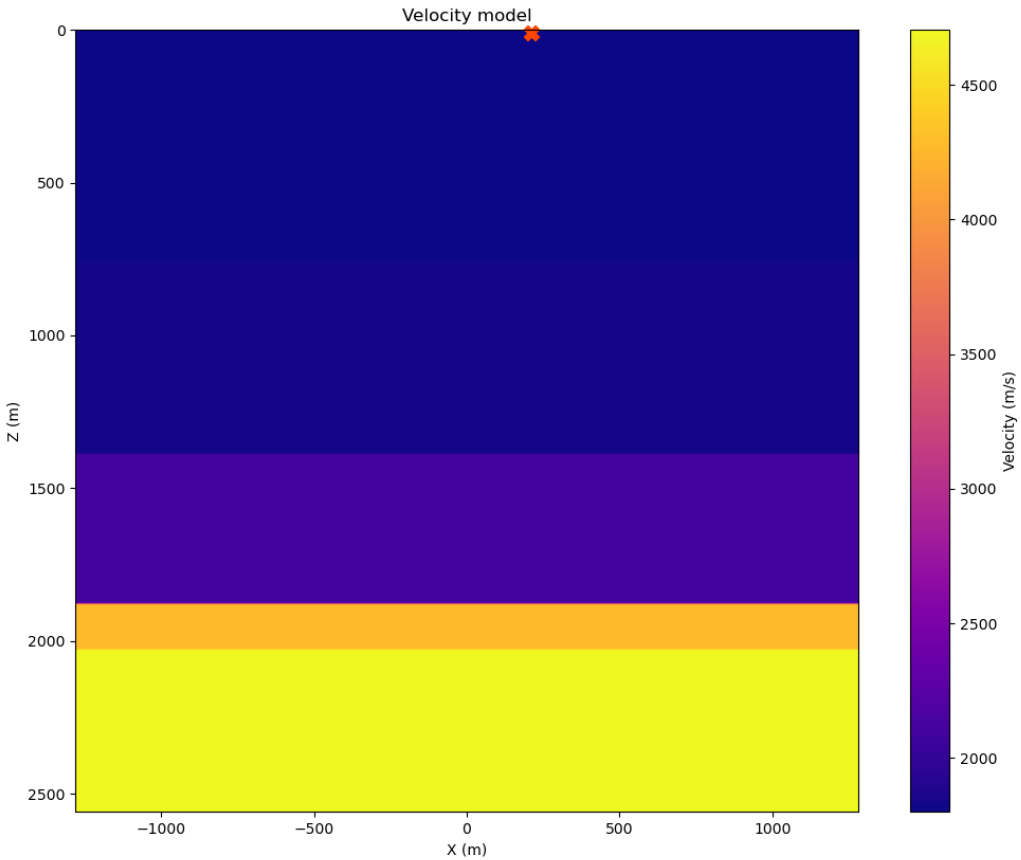

Figure: The velocity model above depicts the velocity of a propagated wave at different locations of a 2D cross section of the subsurface, as represented by the different colors, with a lighter color corresponding to a larger velocity and a darker color corresponding to a smaller velocity. The source location is depicted by the red X on the surface.

Shot Record

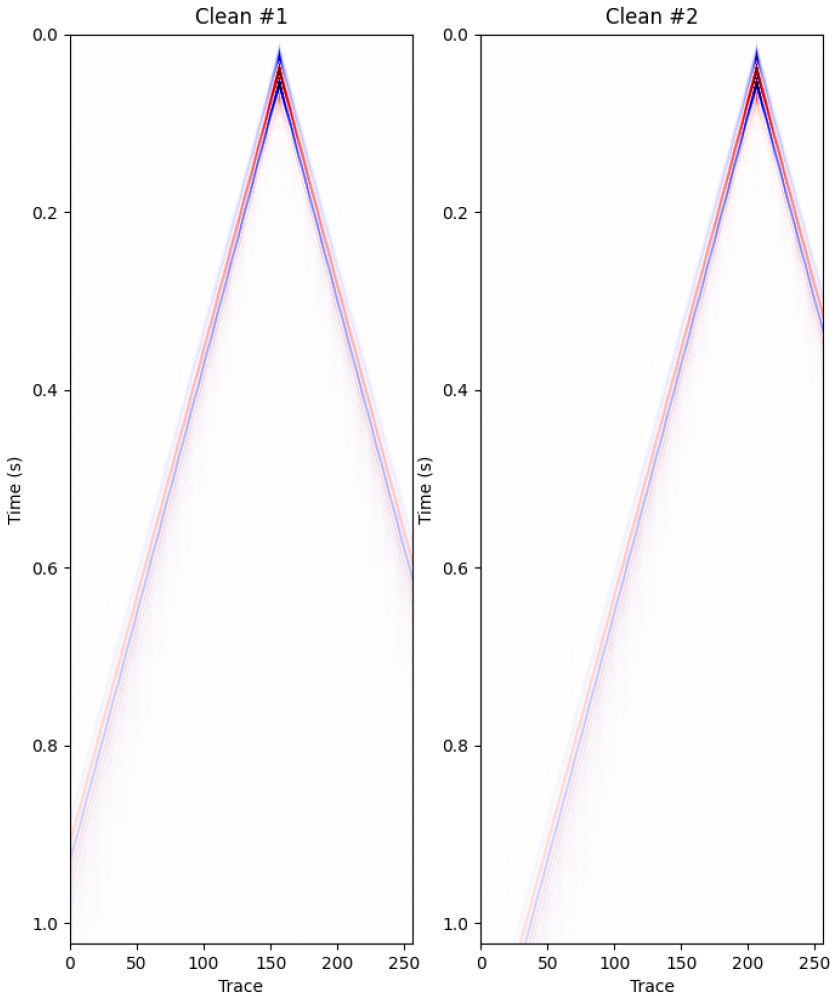

Figure: A wave is propagated from a source location through the subsurface, and a shot record (such as one of those above) is formed by picking up its amplitude from receivers on the surface at different points in time.

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Noise

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- **Coherent noise** — noise which has some apparent pattern (e.g. electric noise, strum noise)
- **Random noise** — noise with no apparent pattern (e.g. Gaussian noise)

Clean/Noisy Shot Records

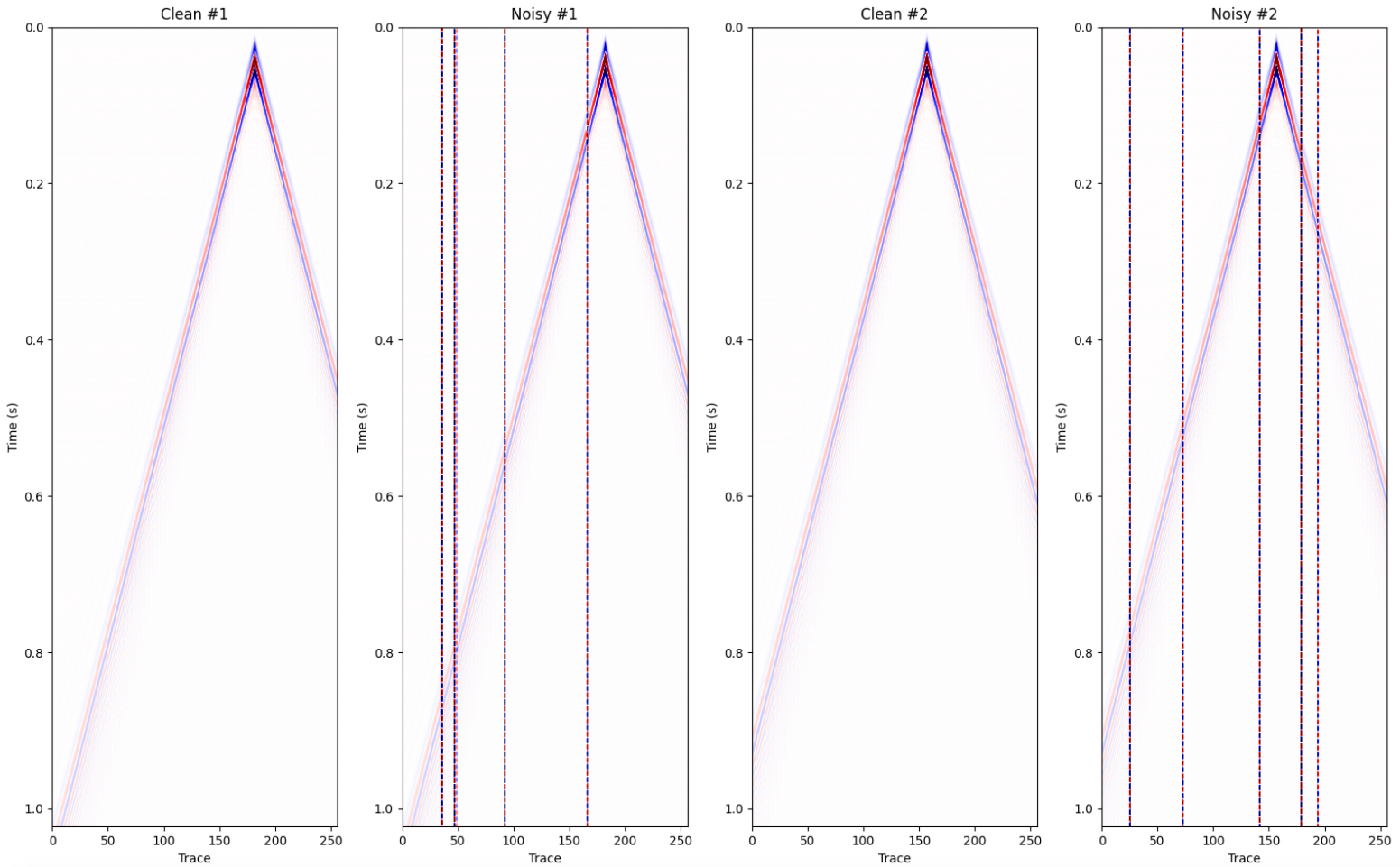
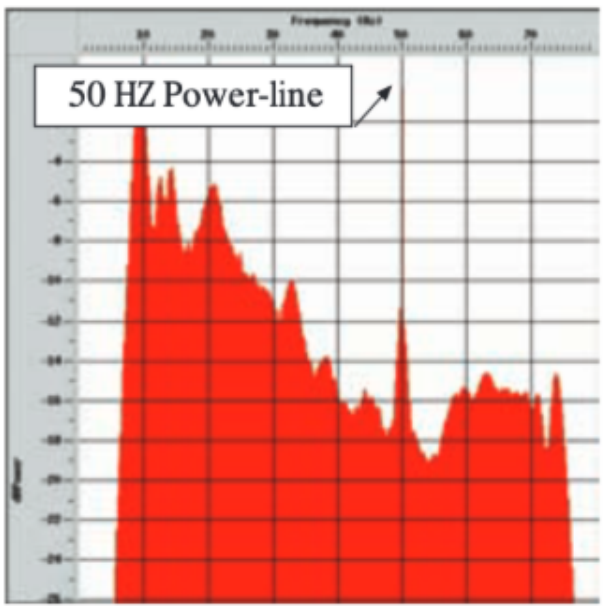
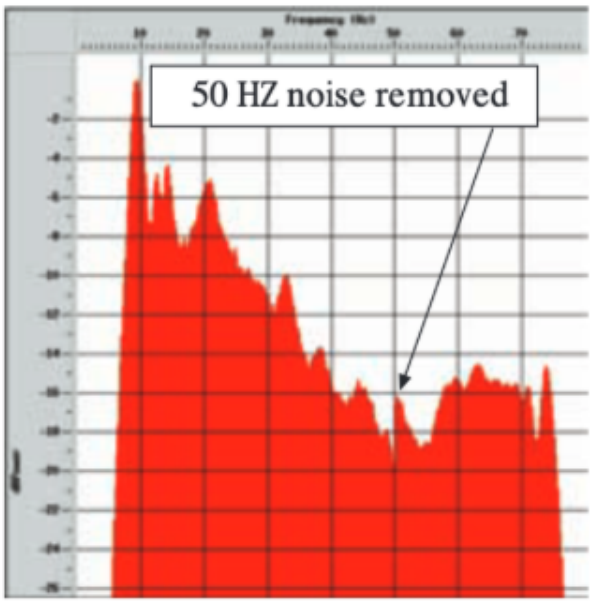


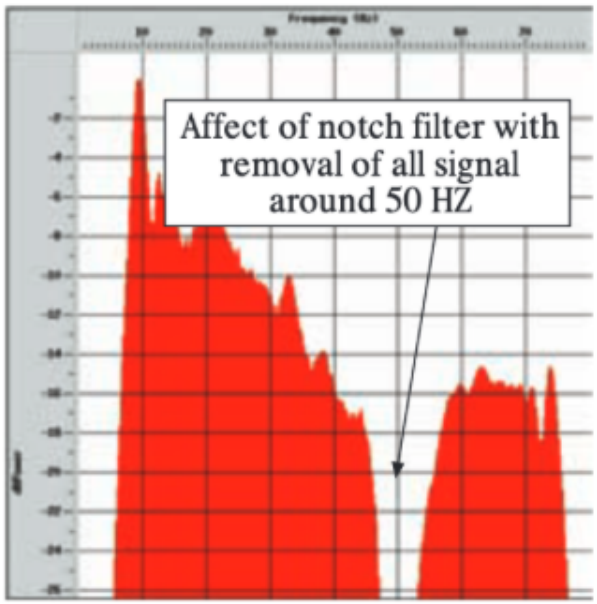
Figure: Clean #1 and Clean #2 show two random images from the dataset of clean shot records. The corresponding shot records with added noise are images Noisy #1 and Noisy #2 from the dataset of noisy shot records. The coherent electrical noise at 60 Hz is present in the form of vertical dashed lines.

Notch Filter

Often, many oil and gas companies use a **notch filter** for noise attenuation, which removes all the data for a particular frequency instead of removing just the noise.







https://www.iongeo.com/virtuals/ResourceArchives/content/documents/Resource%20Center/Technical%20Papers/TP_TS_NoiseAttn_CDingus_101201.pdf

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Pipeline

Create velocity model with sources and receivers

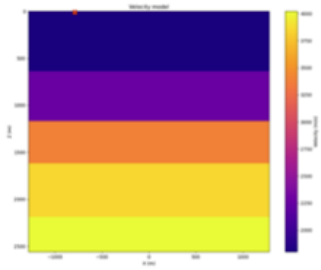
Wave is propagated through the subsurface

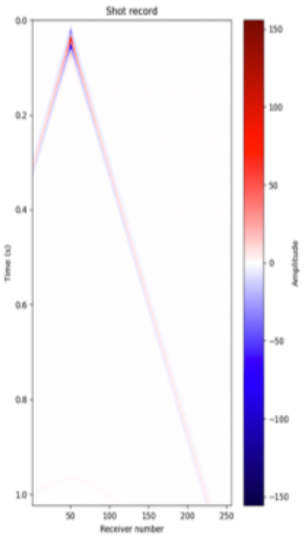
Created a shot gather from velocity model

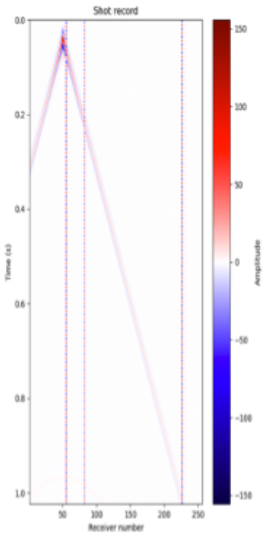
Added noise to shot gather to create noisy dataset

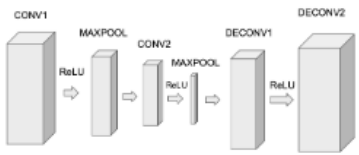
Passed noisy shot gather through our 2D CNN

Analyze difference between denoised and ground truth shot gathers

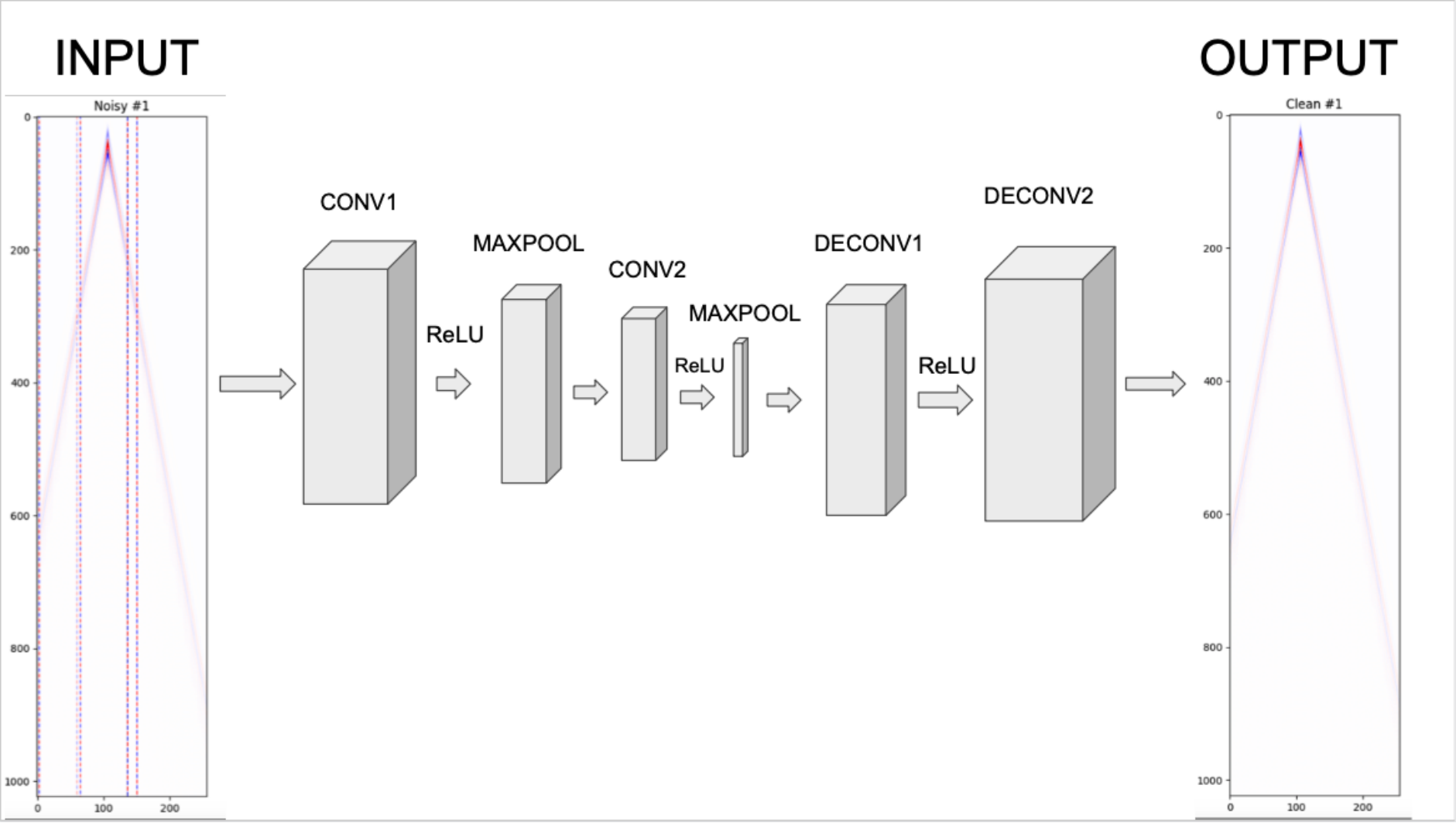








Network Structure



Objective Function

- Analyzed the performance of the model in both the time and frequency domains as they can give a good picture of the quality of noise removal

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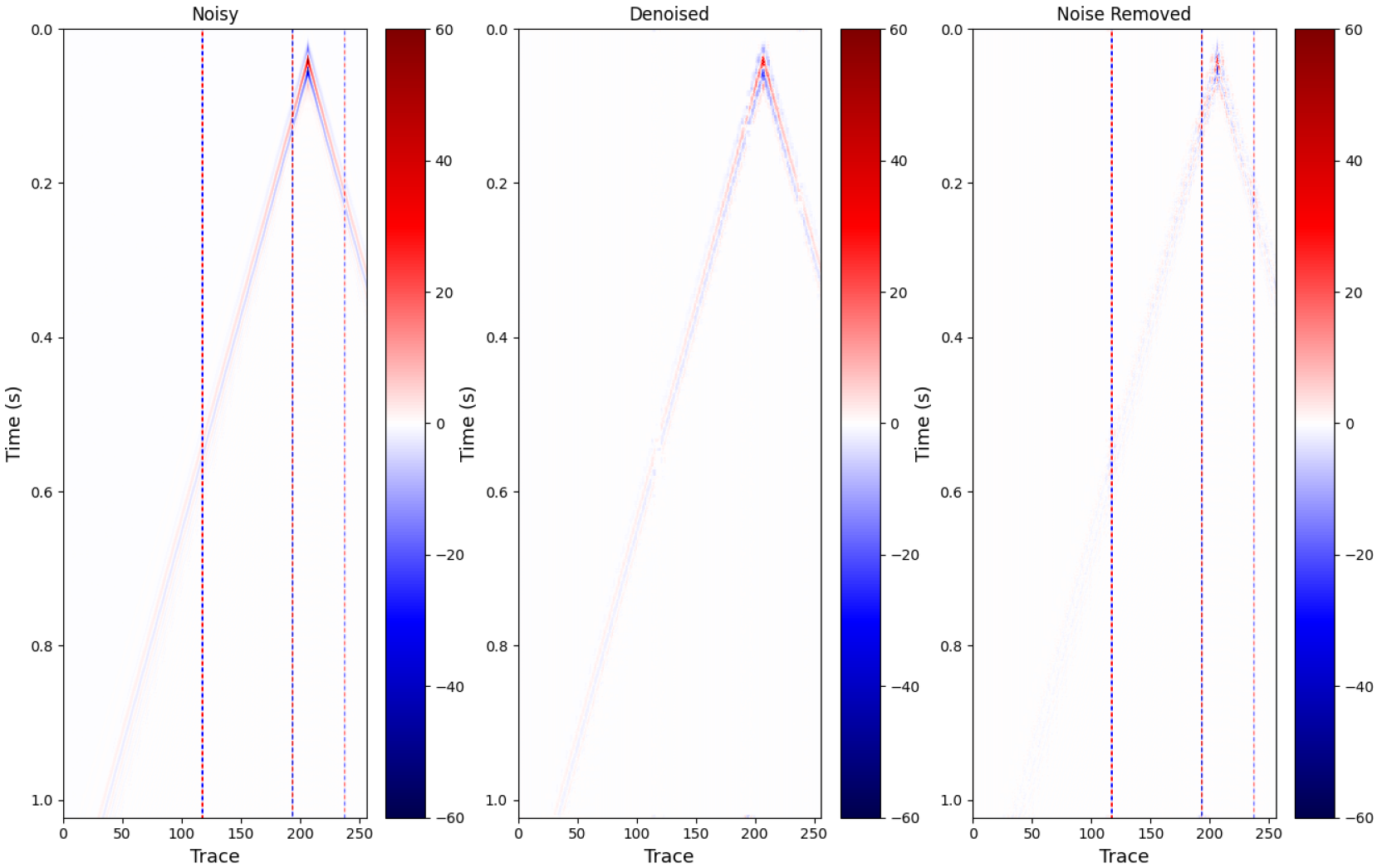
$$\epsilon(\hat{y}_i, y_i) = \boxed{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2} + \boxed{\frac{1}{n}\sum_{i=1}^{n}(\mathcal{F}(\hat{y}_i) - \mathcal{F}(y_i))^2}$$

time domain

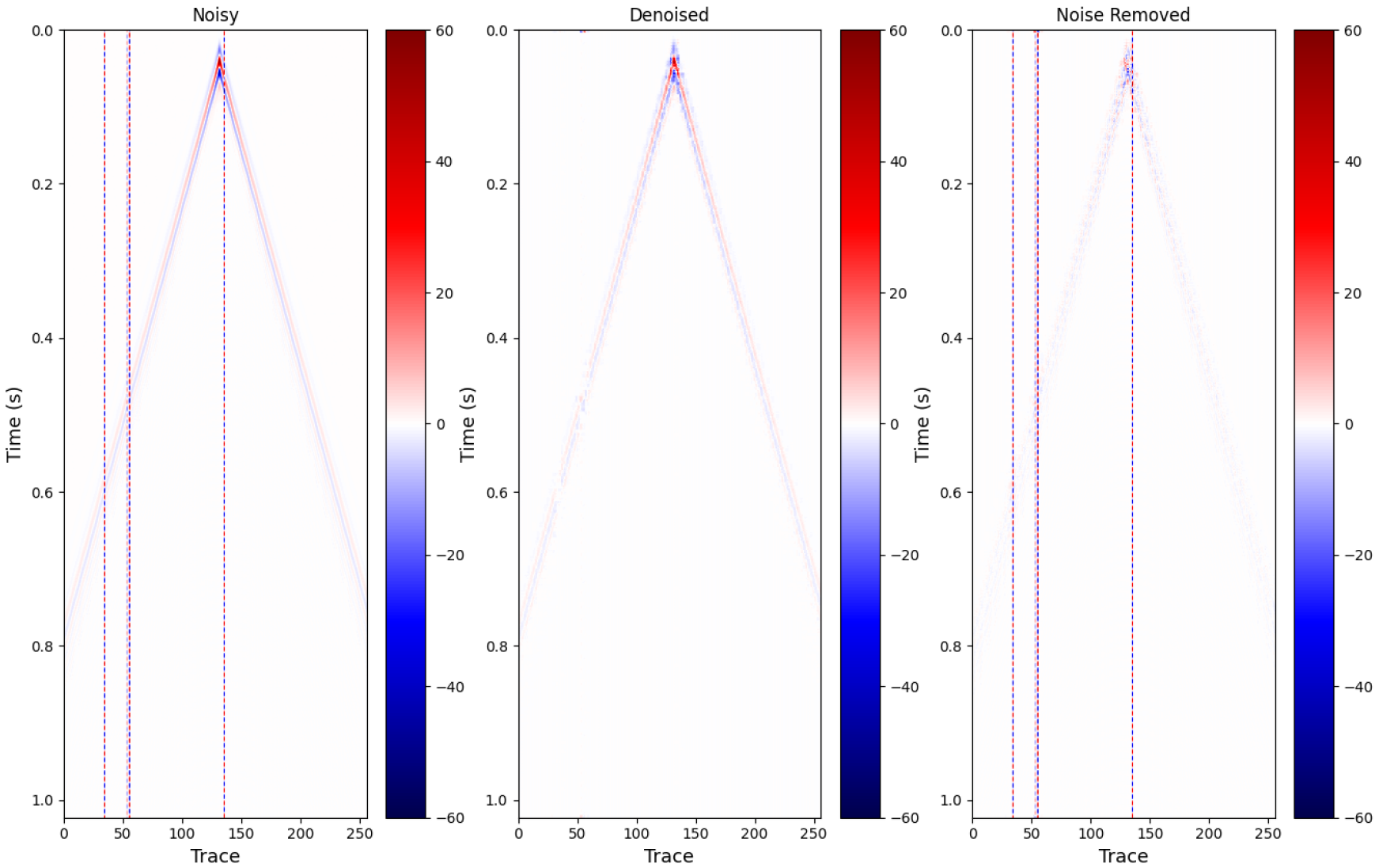
frequency domain

Our Results

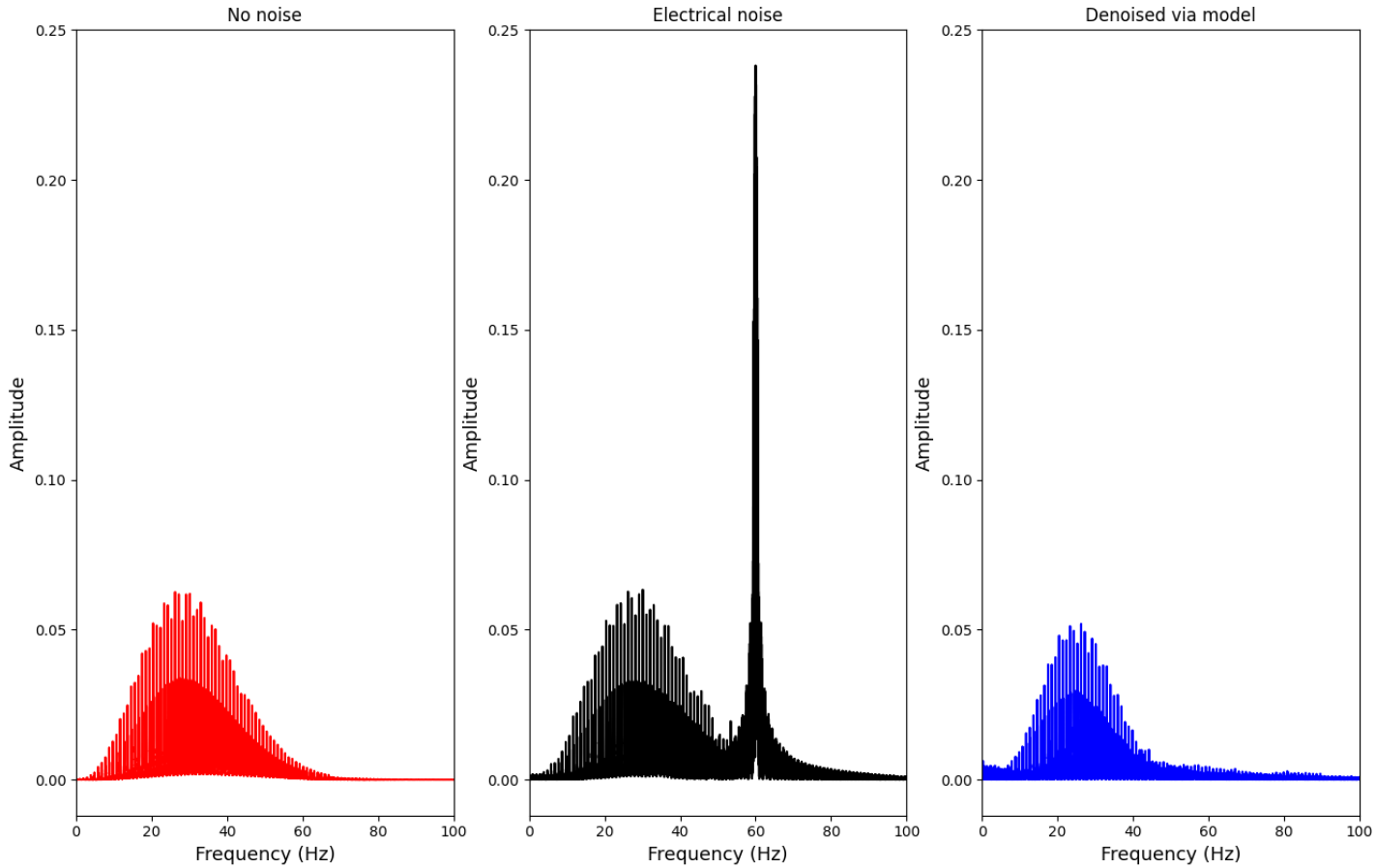
- Our model removes coherent noise quite well while still retaining most of the characteristics of the original shot record



Our Results


Noisy
Denoised
Noise Removed
Time (s)
Trace
0.0
0.2
0.4
0.6
0.8
1.0
0
50
100
150
200
250
60
40
20
0
−20
−40
−60

Our Results



Errors	
Normalized L1	2.3798×10^{-4}
Normalized MSE	7.6384×10^{-6}

Future Works

- Use more complex velocity models to strengthen model against common barriers in noise attenuation such as faults, folds, and salt

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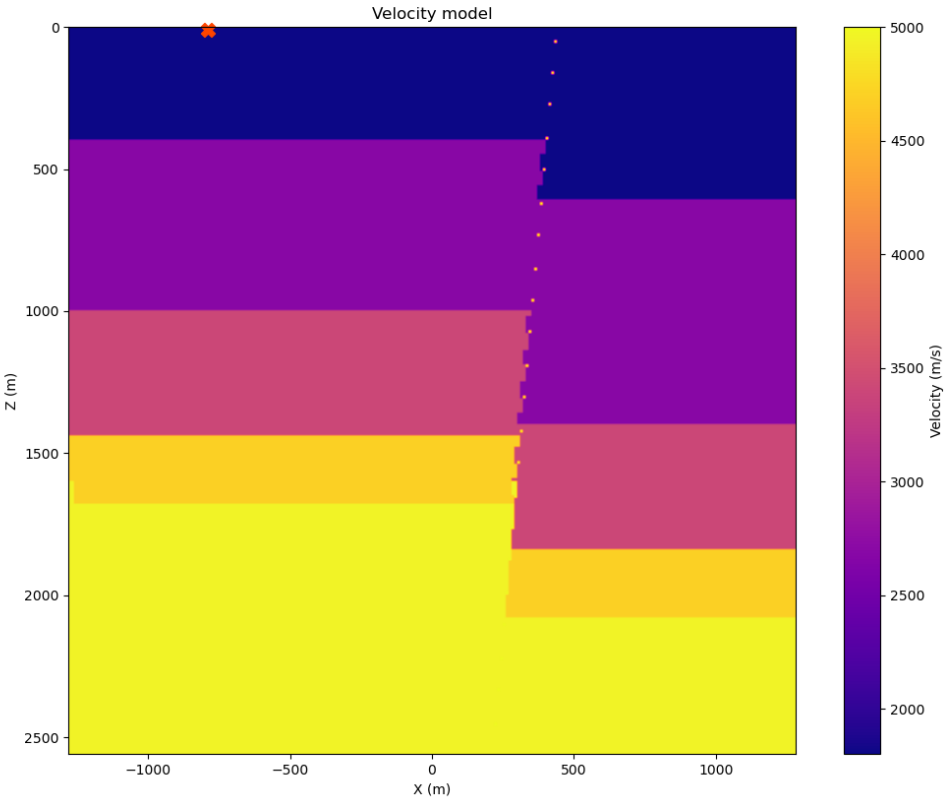
- Use some type of adaptive coefficients of the loss function's representations in the time and frequency domains, where the difference in the frequency domain should be most pronounced
- Use sparse dictionary learning, which can provide further insight behind the underlying process separating the signal from the coherent noise

More Complex Velocity Models



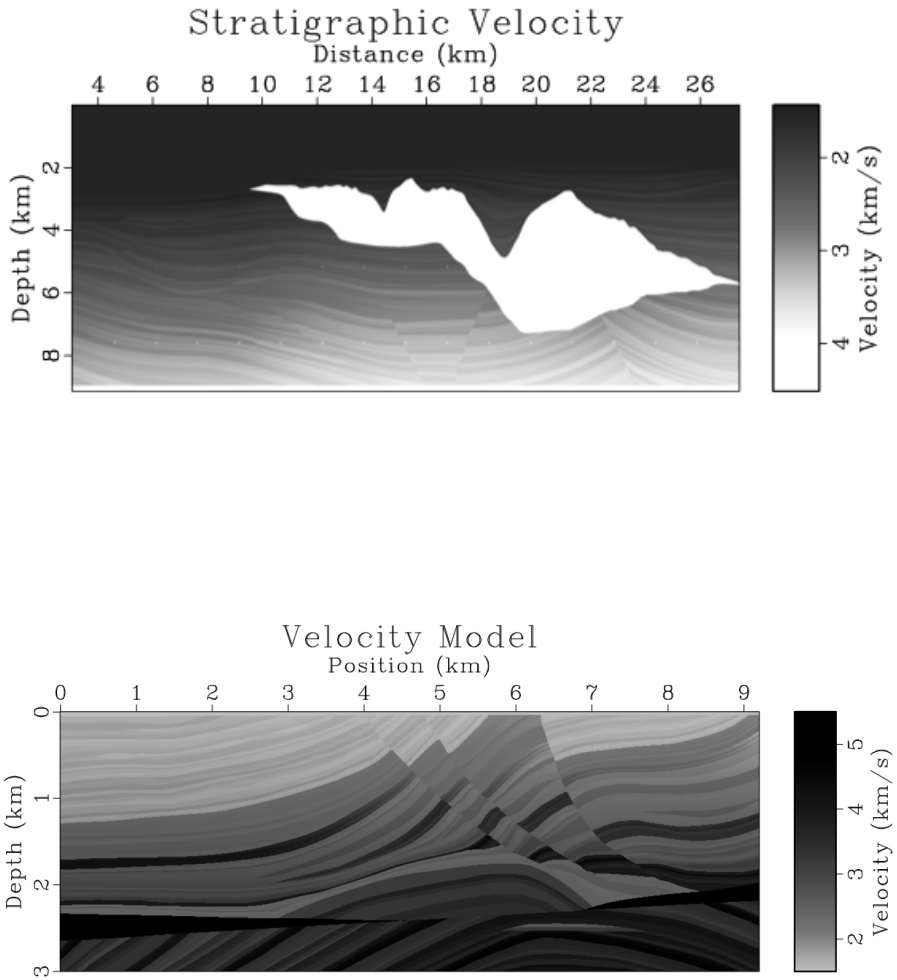


Figure 1: Velocity model

https://reproducibility.org/RSF/book/data/sigsbee/paper.pdf
https://reproducibility.org/RSF/book/data/marmousi/paper.pdf

Acknowledgements

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