

Practical multicomponent land FWI

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**NSERC
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FACULTY OF SCIENCE
Department of Geoscience



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- Land multicomponent FWI remains a challenge in seismic processing
- These challenges include:
 - Unknown source wavelet
 - Heterogenous near-surface
 - Low S/N ratio
- VSP data sets provide data with:
 - Better S/N ratio than surface seismic
 - Since receivers are located in the borehole only the source side propagation is affected by near-surface heterogeneities.
- Understanding how the pre-processing of VSP data impacts the FWI performance is key for developing robust workflows.



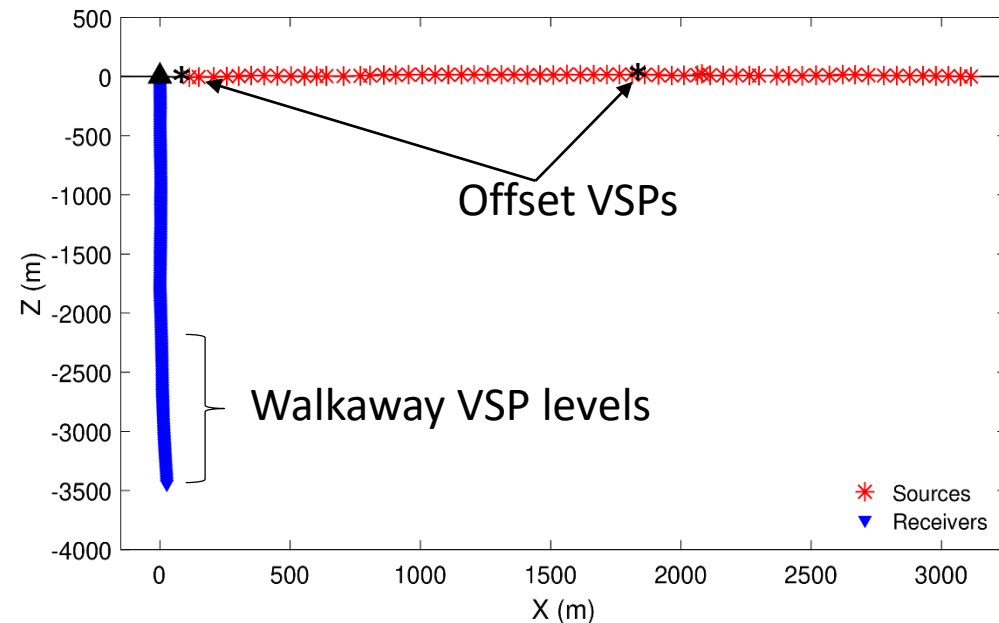
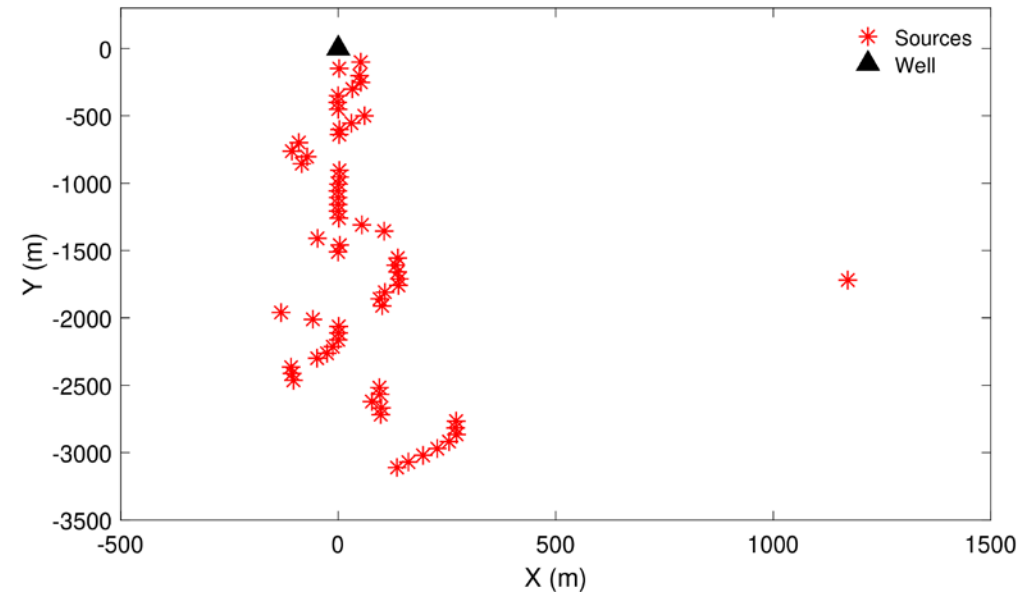
Acquisition geometry

Source parameters:

- 62 source points @ 50 m spacing
- Linear sweep, 2-140 Hz, 16 s length, 0.5 s cosine tapers.

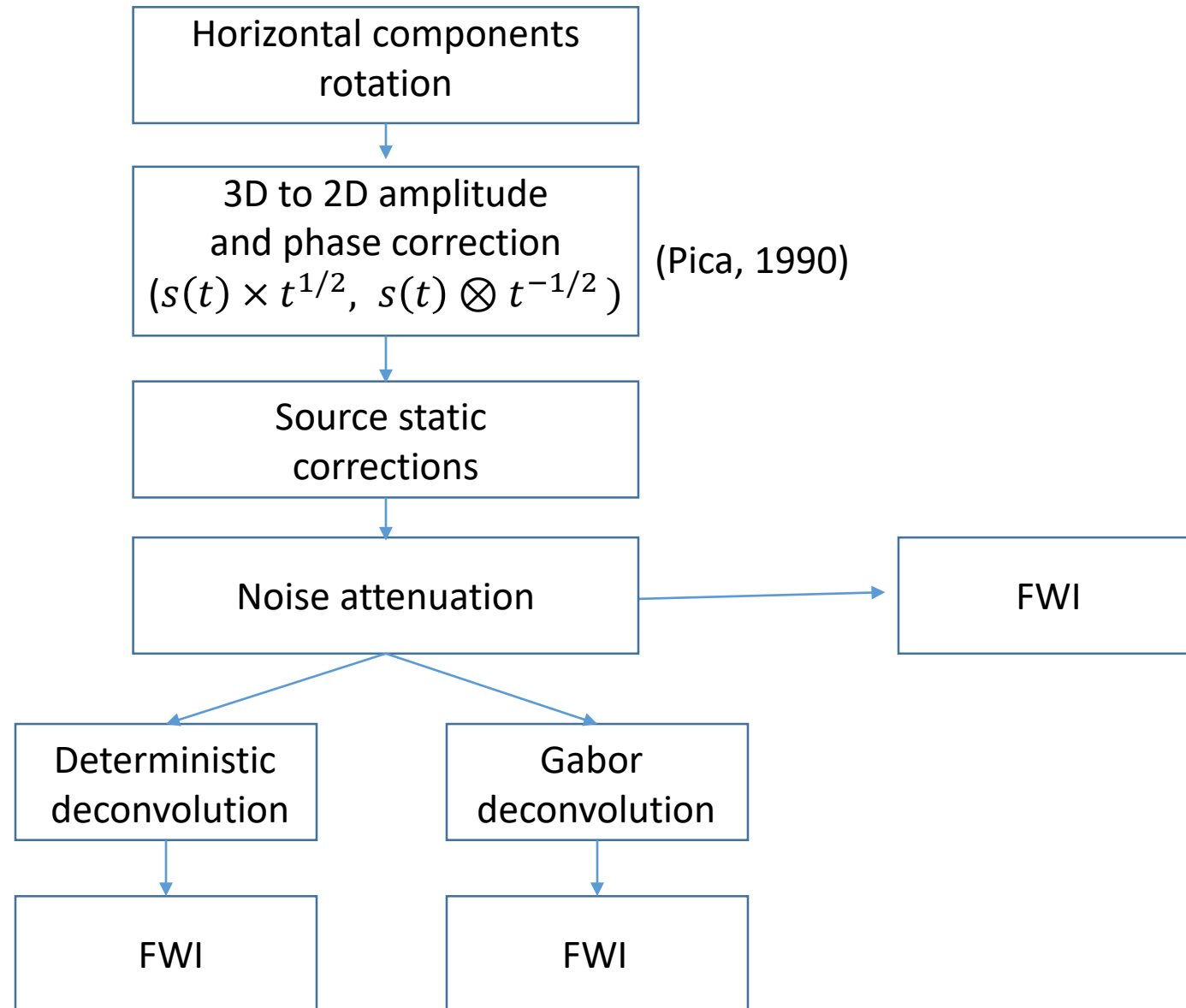
Receiver parameters:

- 229 receiver levels @ 15 m spacing (16.7 m – 3445.6 m)
- 3C digital geophones in a string of 43 receivers at six array levels.
- Only the geophone levels between 2302 m and 3445 m were recorded for all source locations





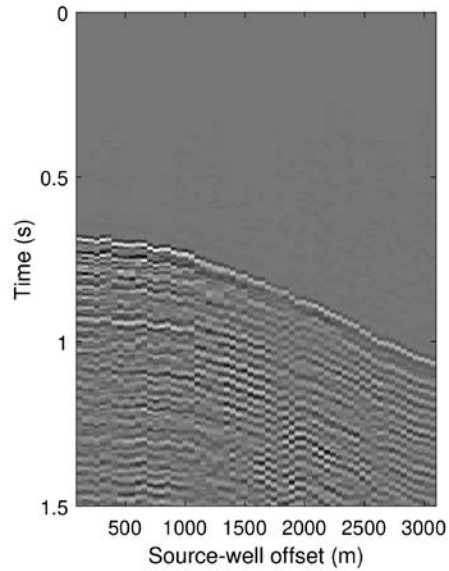
Processing workflow



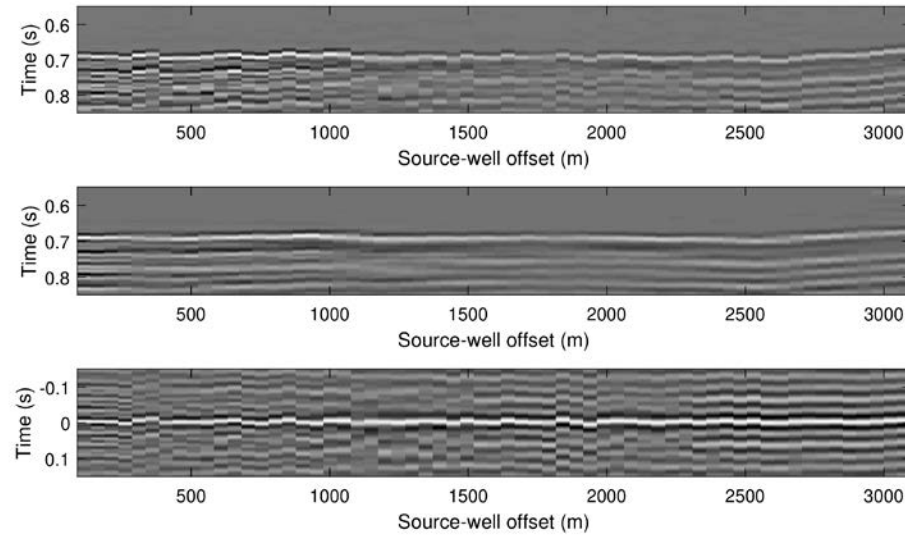
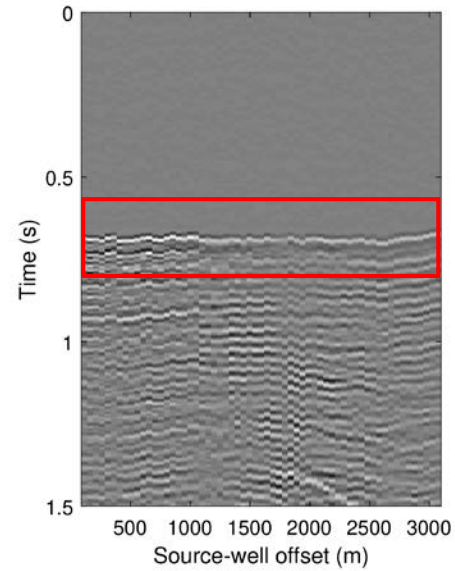


Near-surface corrections

Rec-gather



NMO corrected
rec-gather



NMO corrected
first arrivals

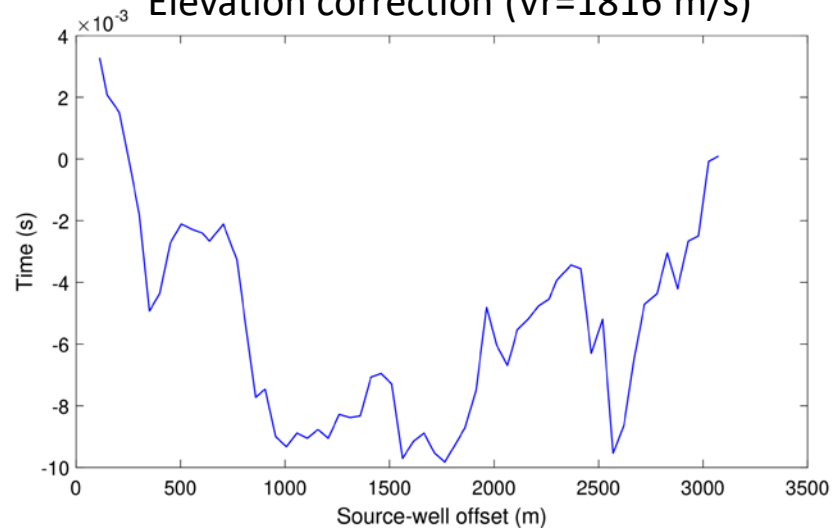
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Pilot traces

=

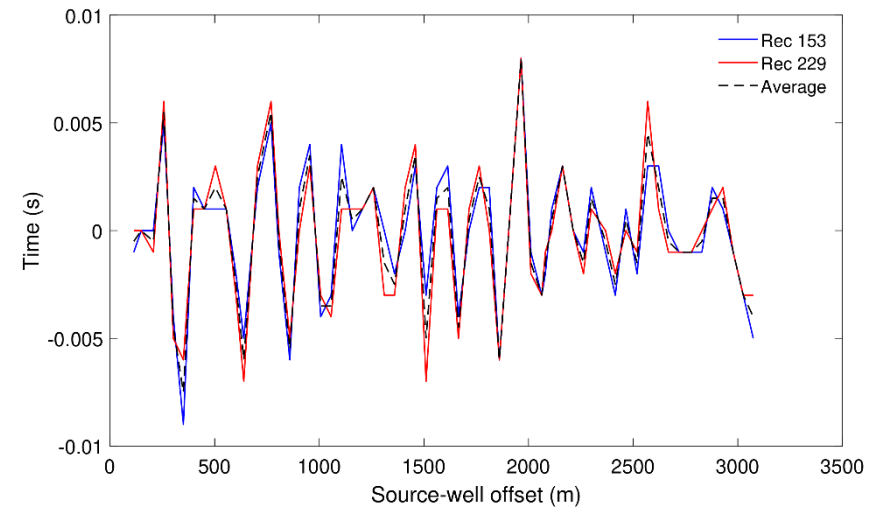
Residual statics

Elevation correction ($V_r=1816$ m/s)



+

Residual statics

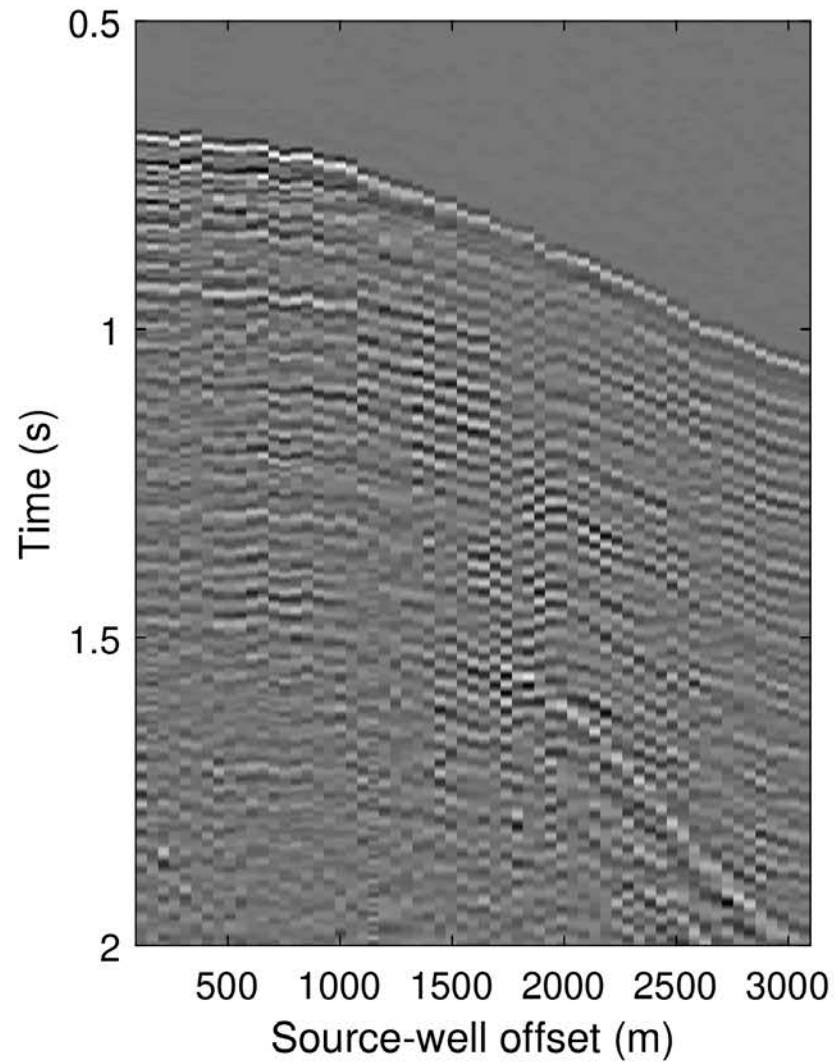


= Total statics
(source side)

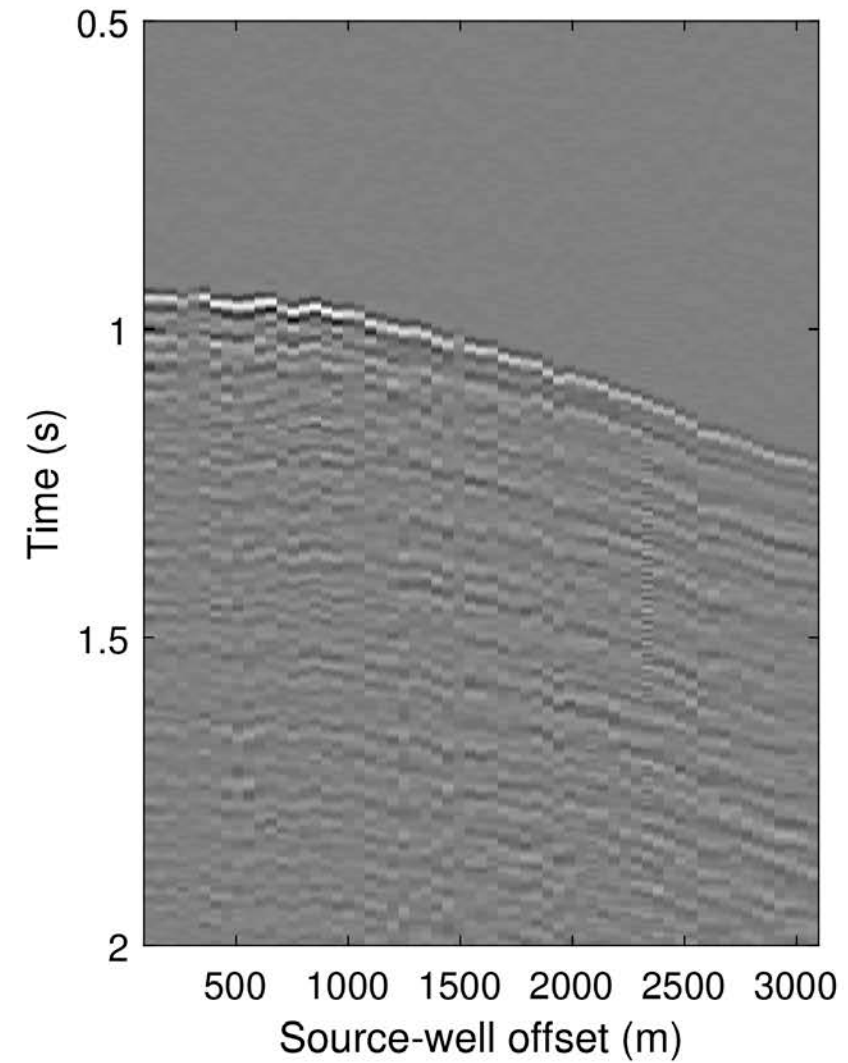


Receiver gathers before static corrections

Rec @ 2302 m depth



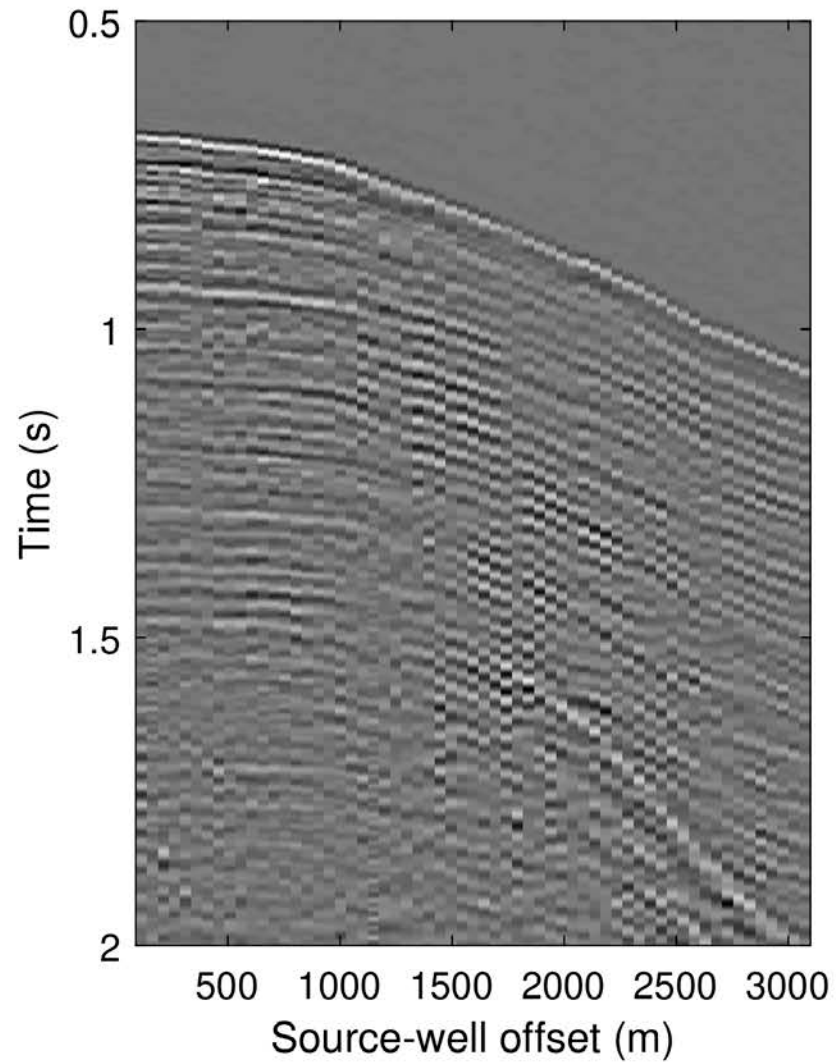
Rec @ 3445 m depth



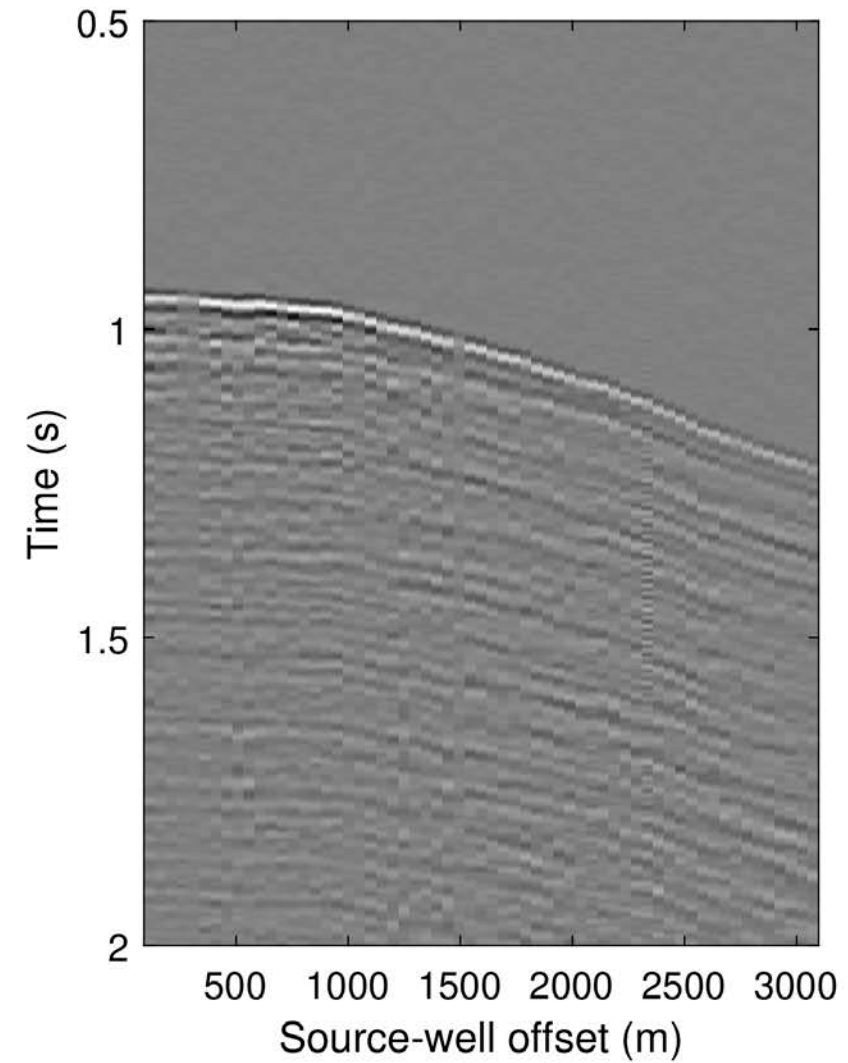


Receiver gathers after static corrections

Rec @ 2302 m depth

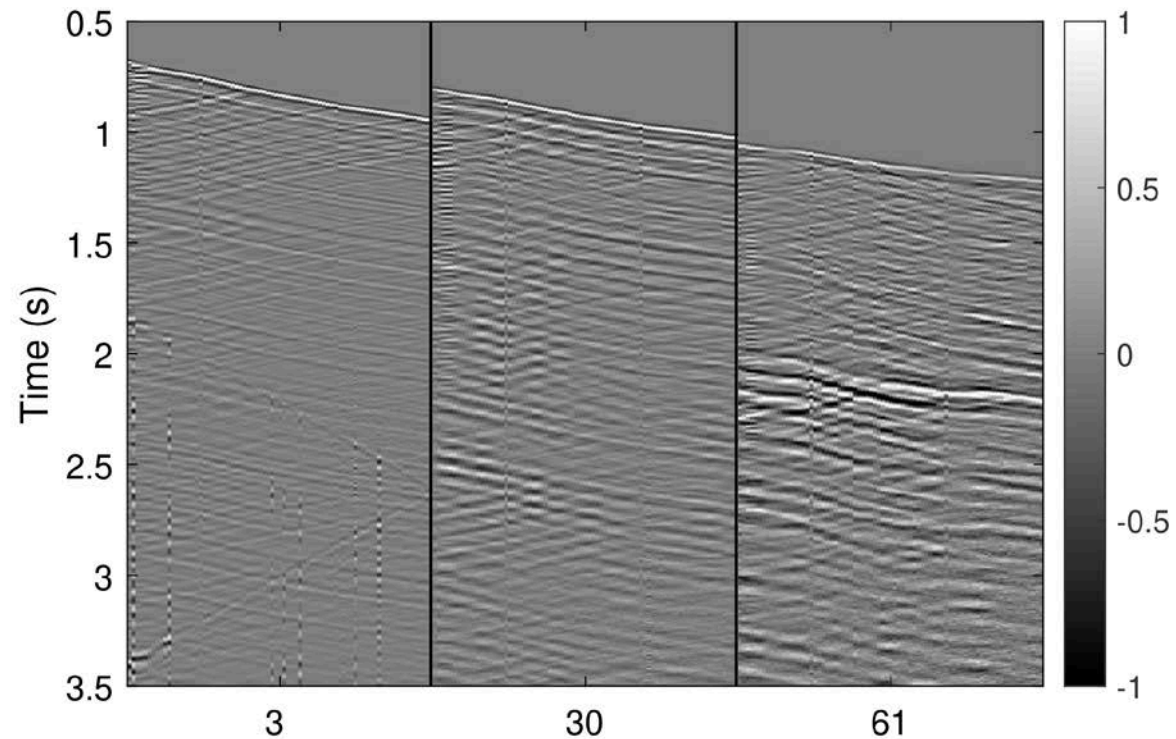


Rec @ 3445 m depth

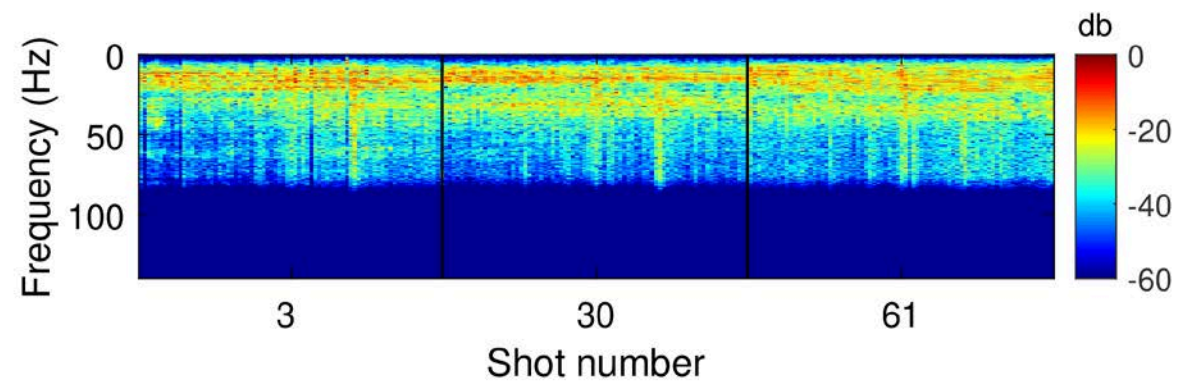
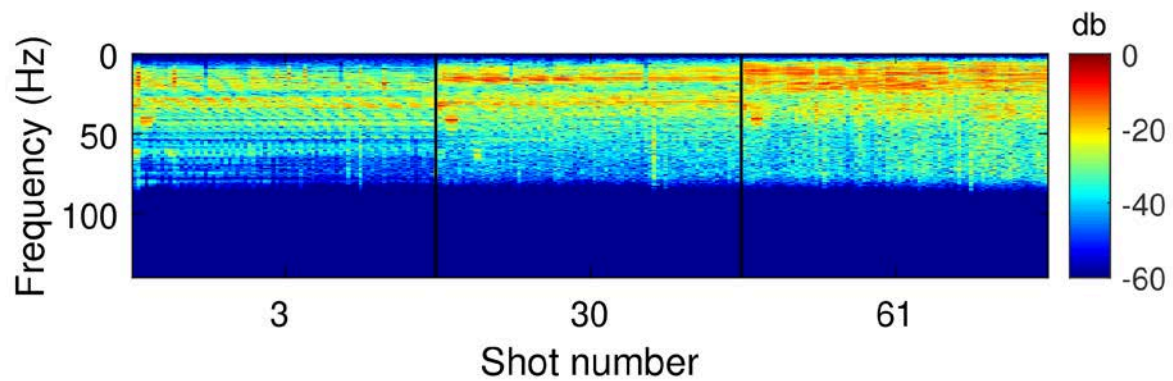
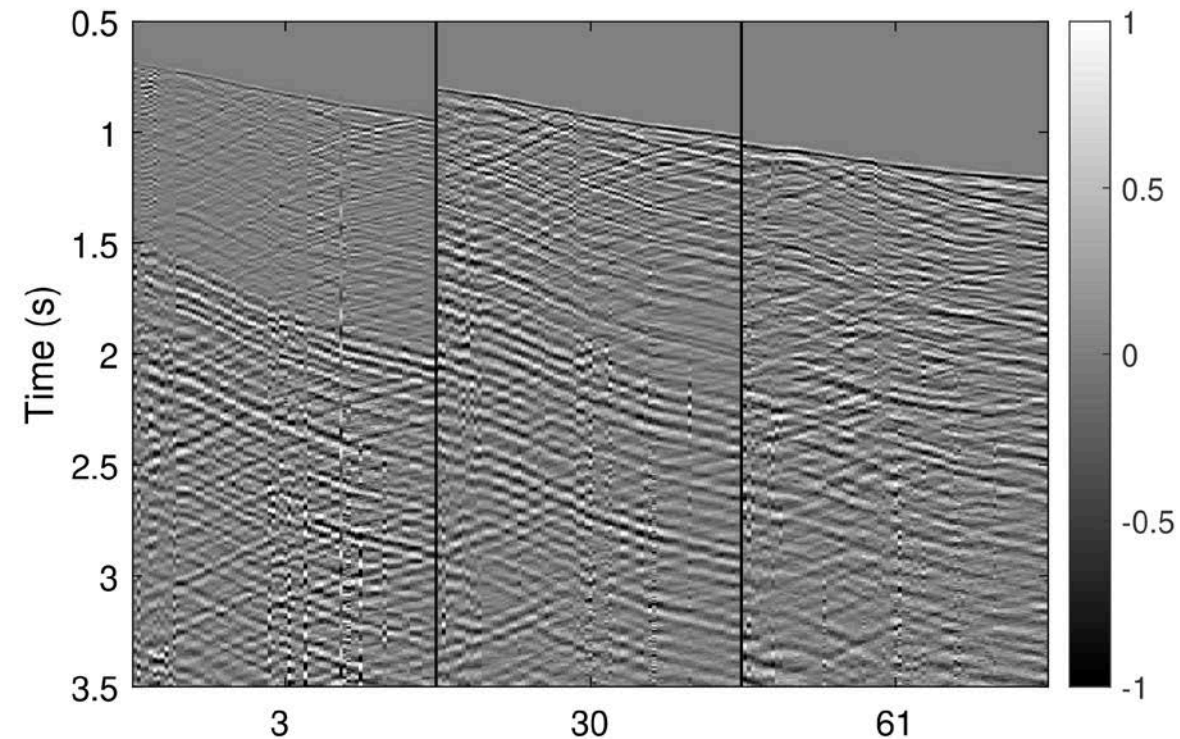


Data before noise attenuation

Vertical component



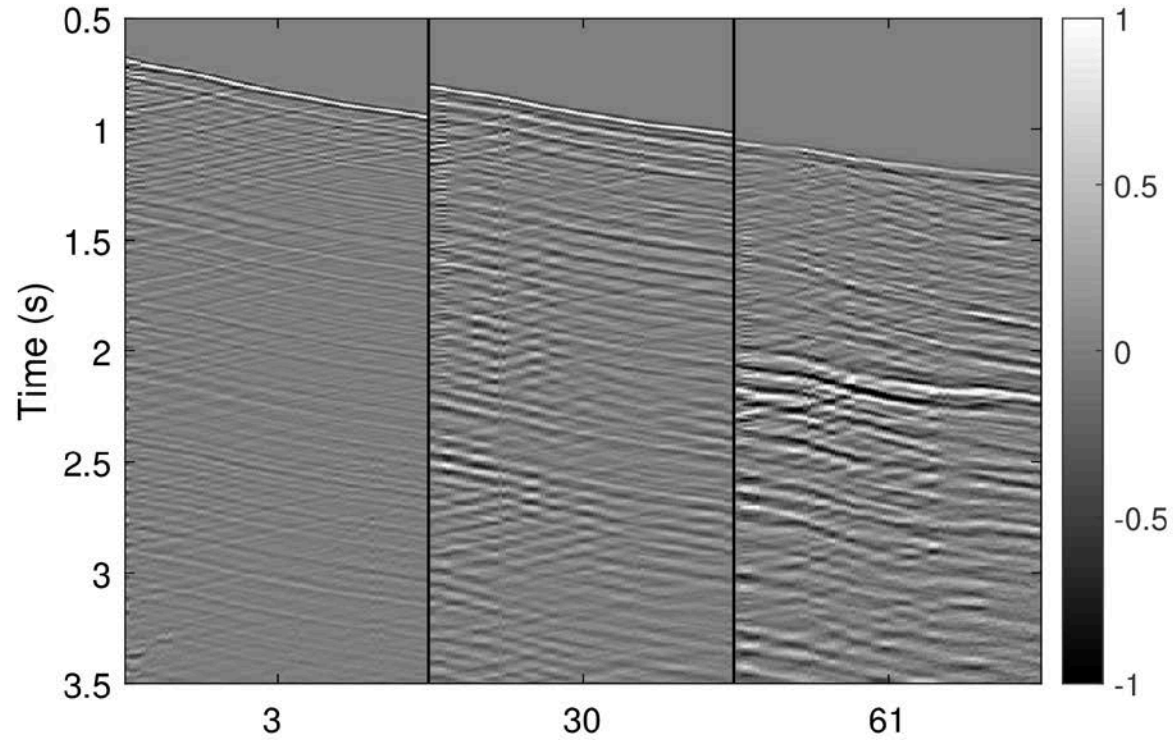
Horizontal component



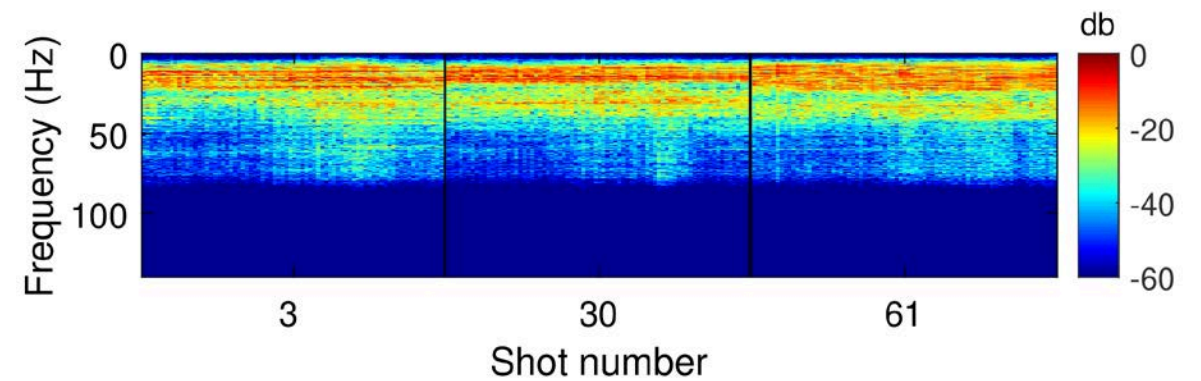
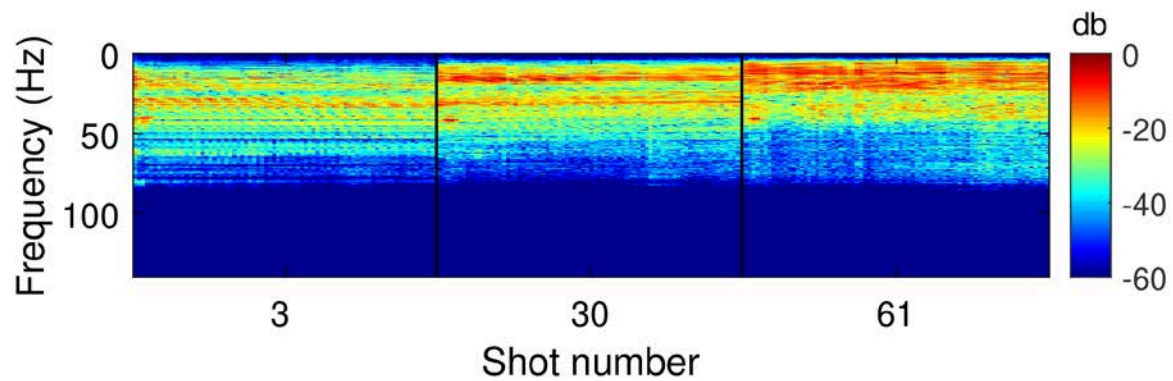
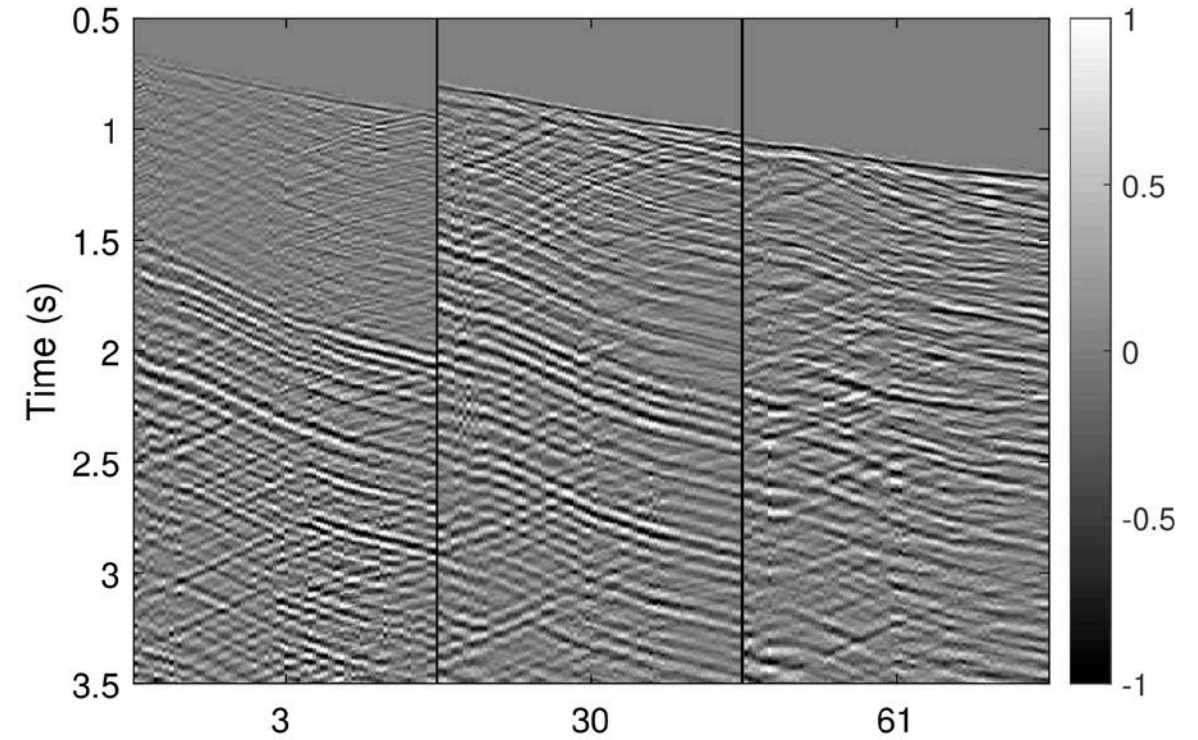


Data after noise attenuation (FX filter, 7 points)

Vertical component



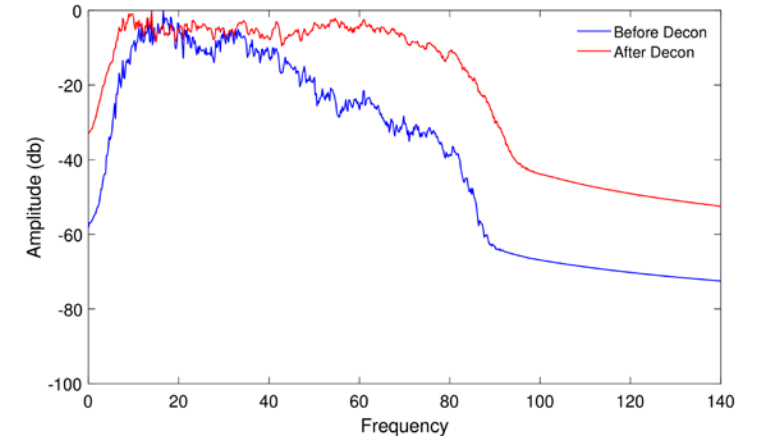
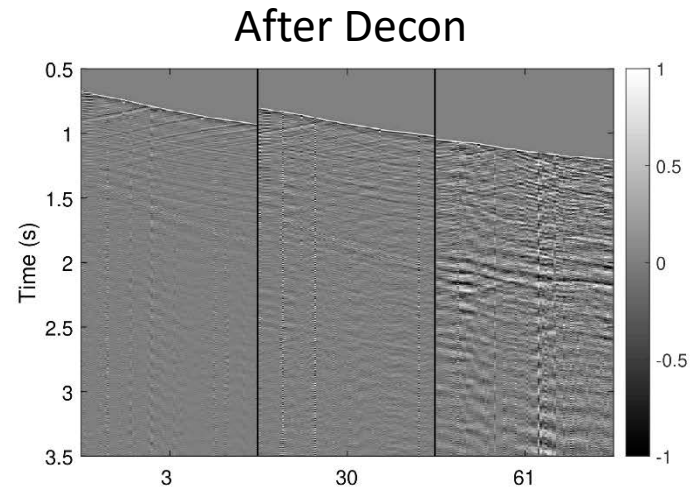
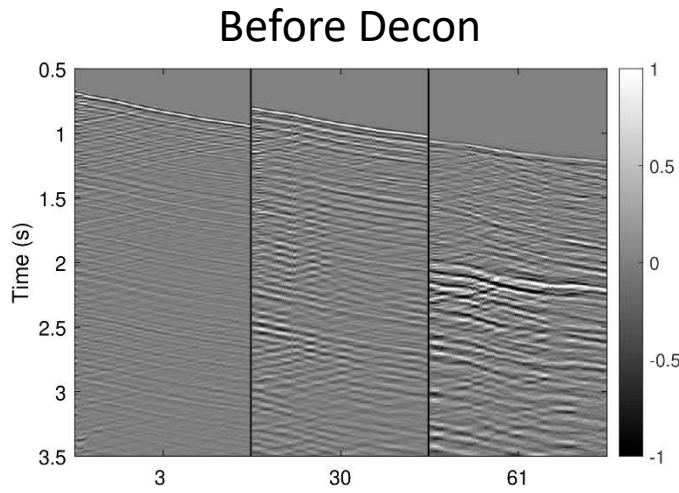
Horizontal component



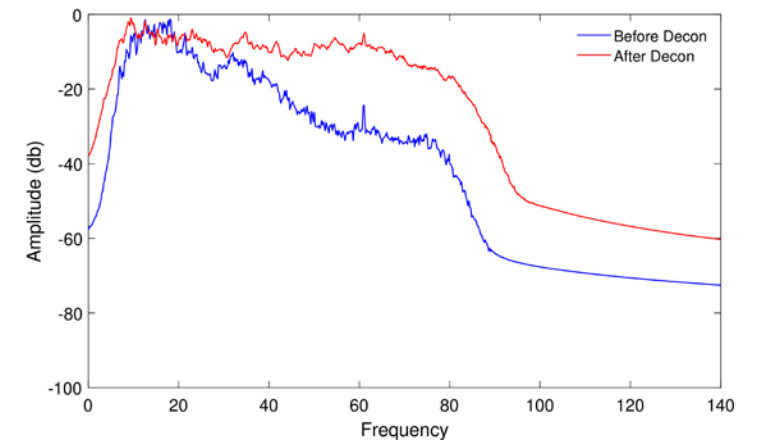
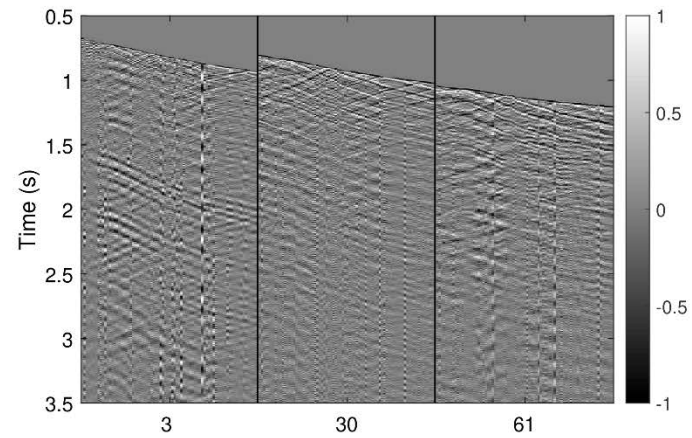
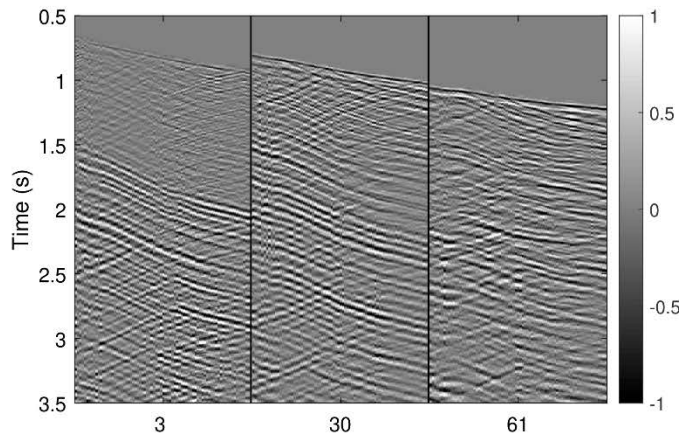


Deterministic Decon

Vertical component

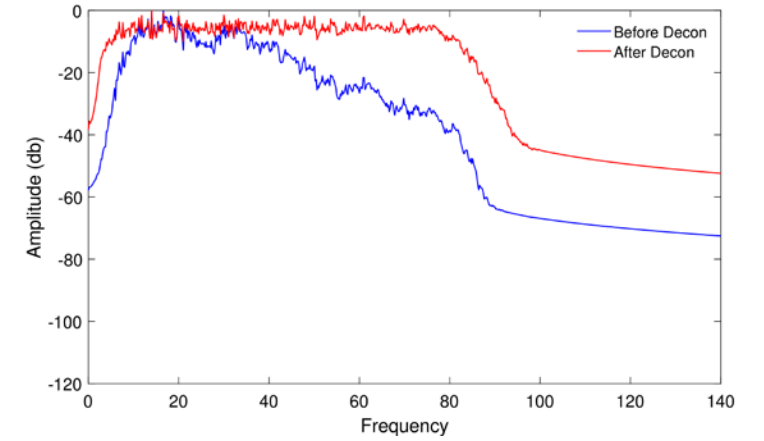
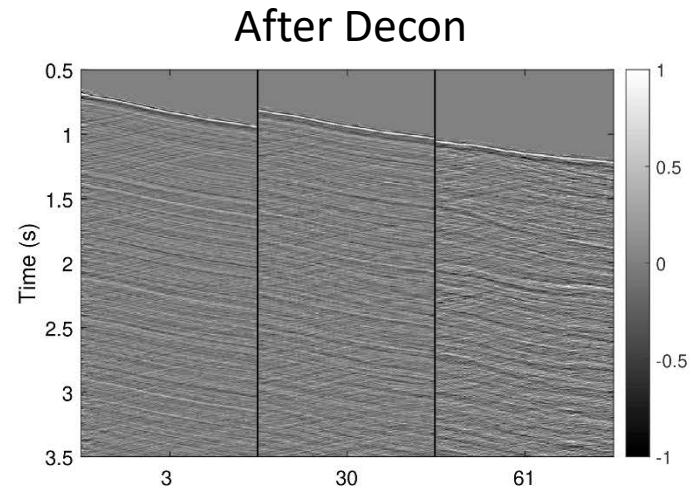
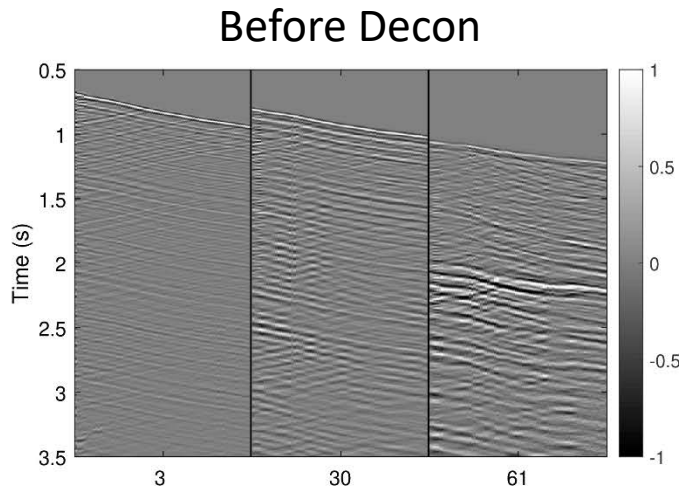


Horizontal component

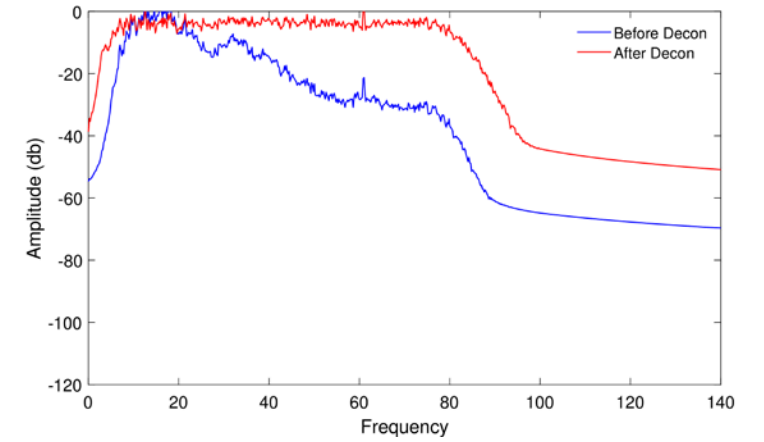
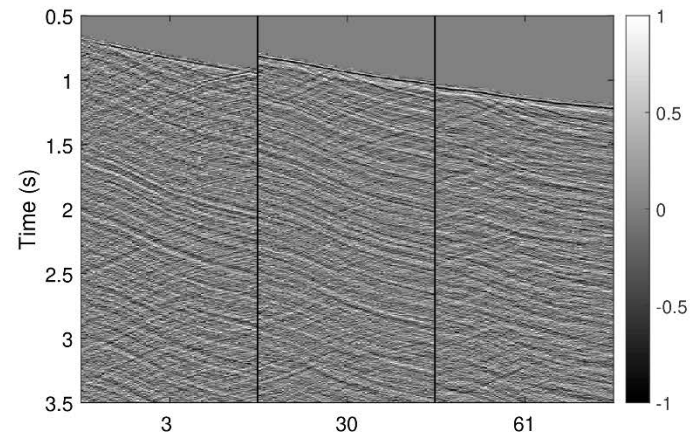
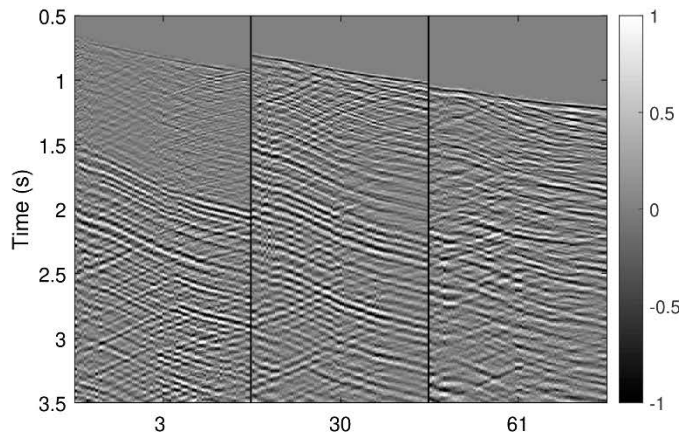




Vertical component



Horizontal component





Initial models used for the inversion

- Smoothed well logs were used as initial models.
- 8 source points between 113 m and 1812 m offset were used in the following tests.
- We only inverted for V_p and V_s . No model updates were applied to the density model.

Depth windows

250-1000 m

750-2250 m

2000-3500 m

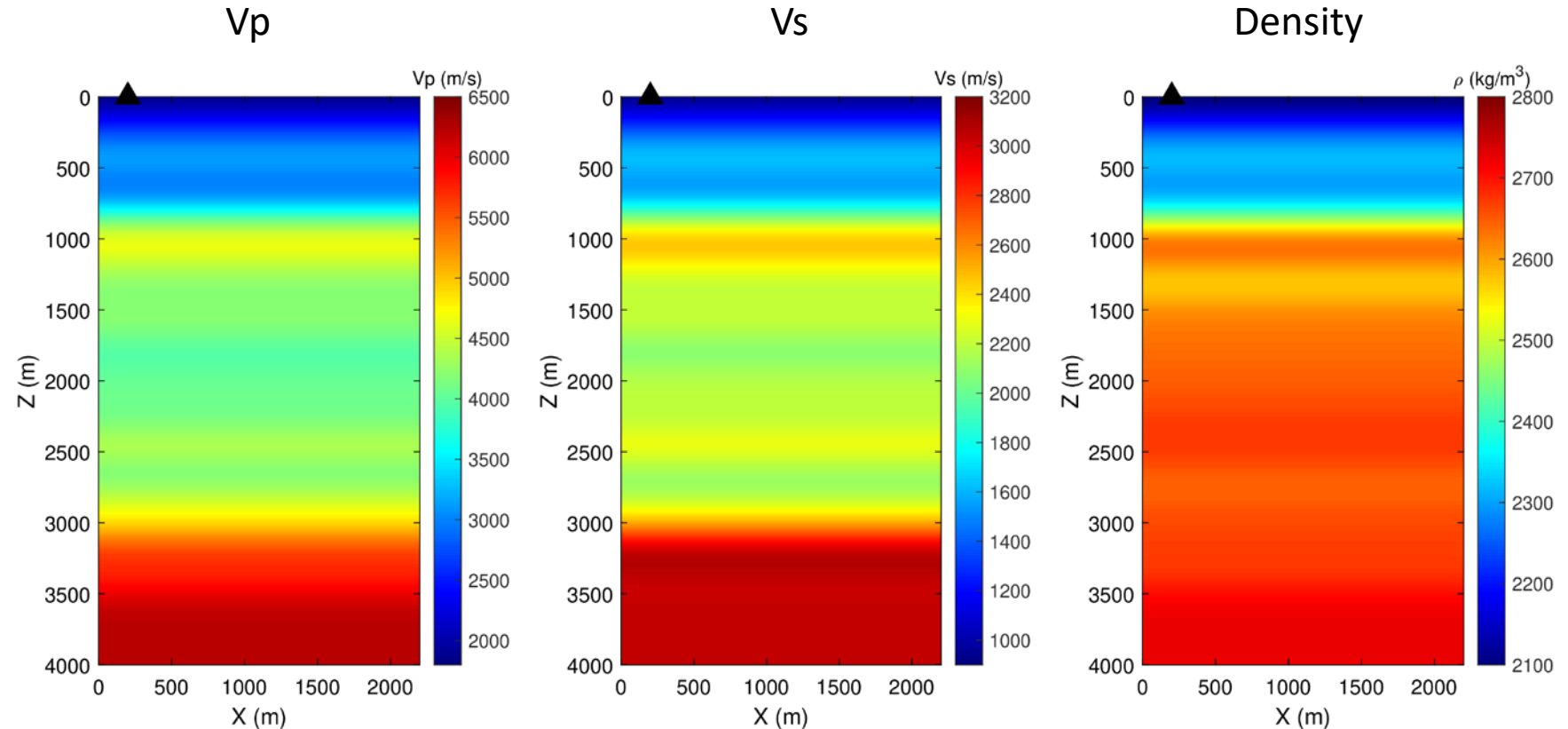
Frequency scales

4-8 Hz

4-12 Hz

4-16 Hz

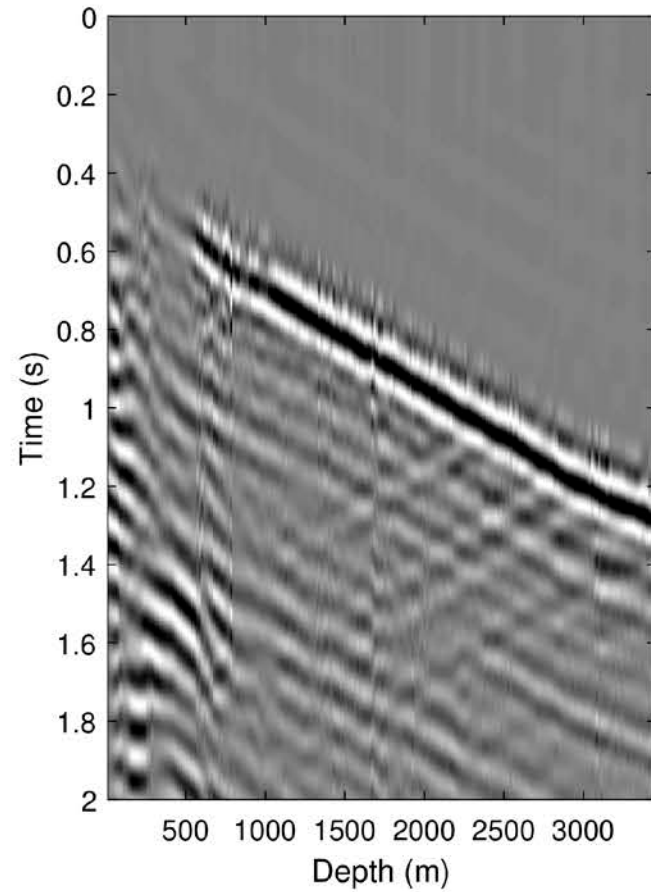
4-20 Hz



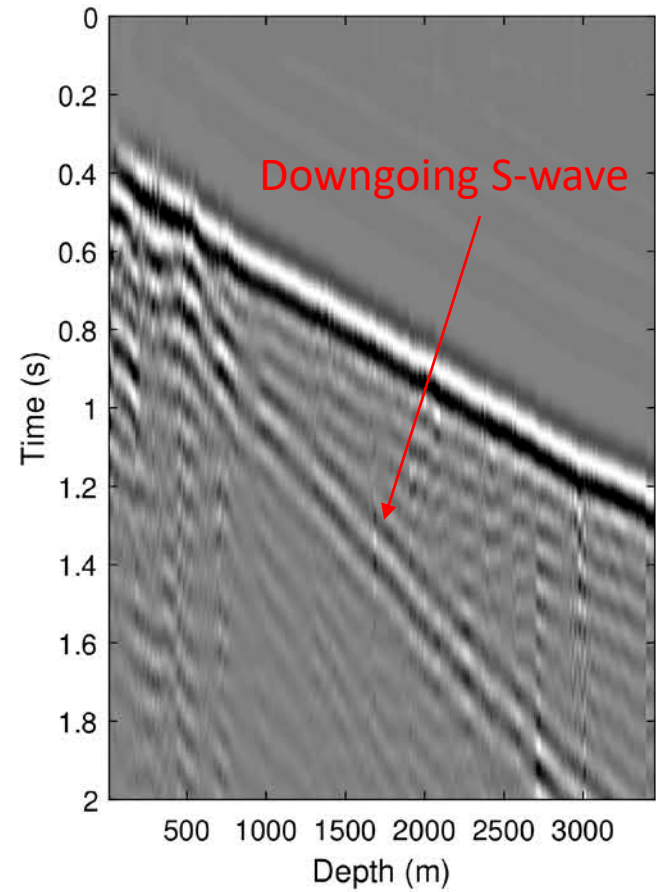


First scale [4-8 Hz], near-offset data

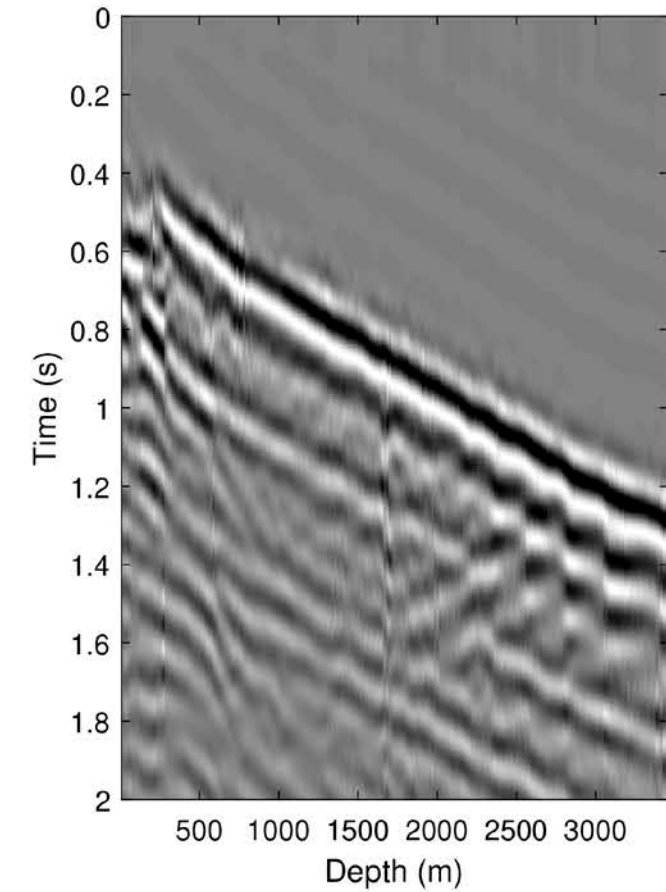
No decon



Deterministic decon

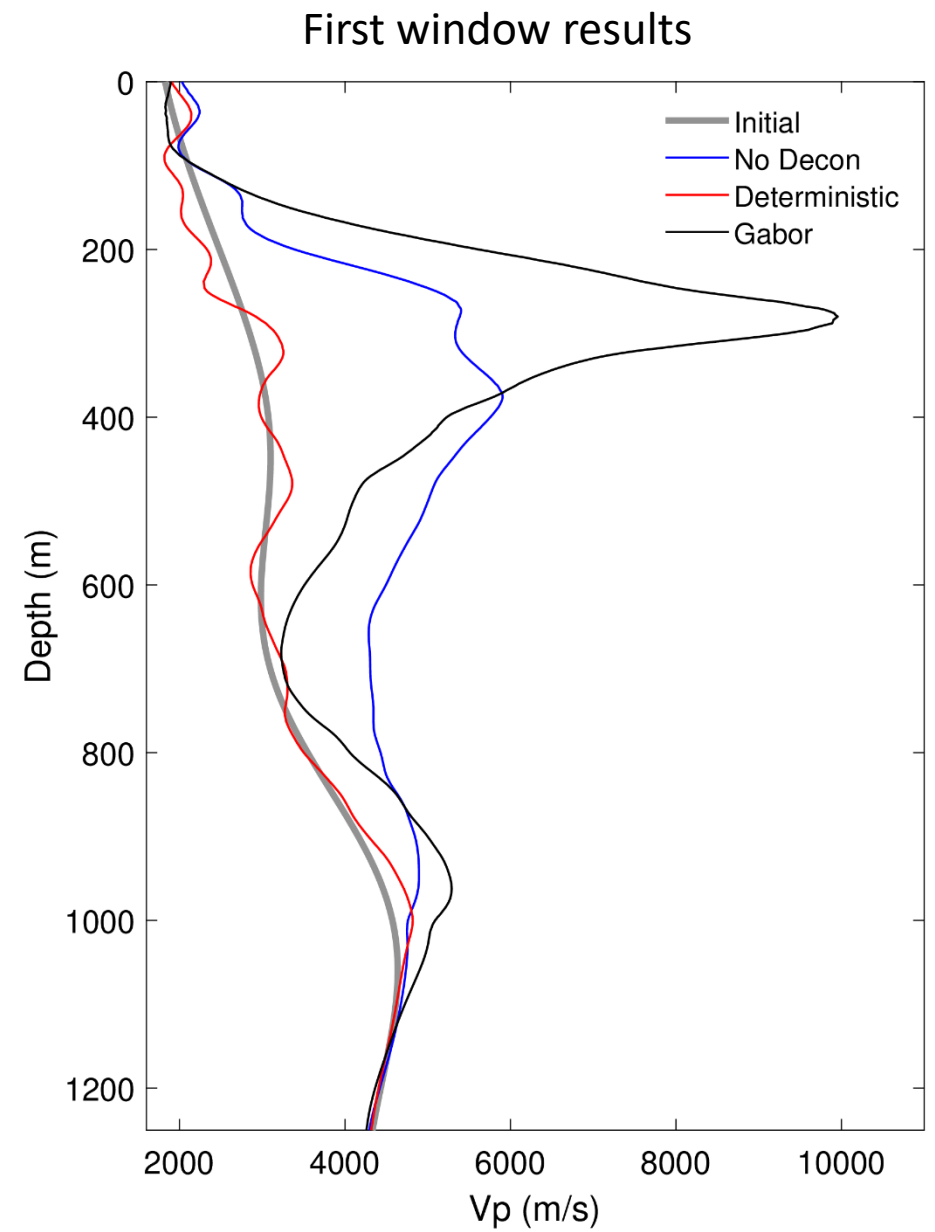
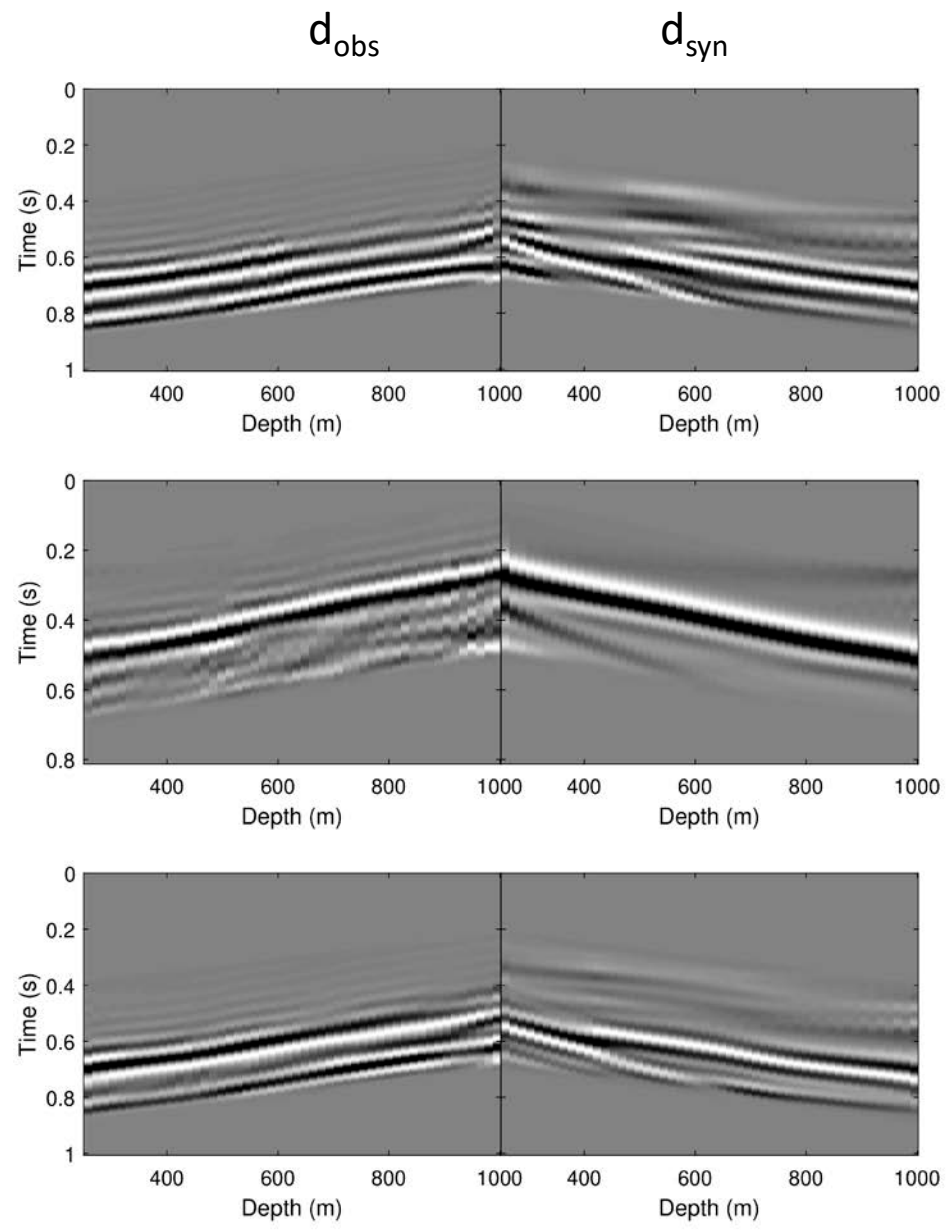


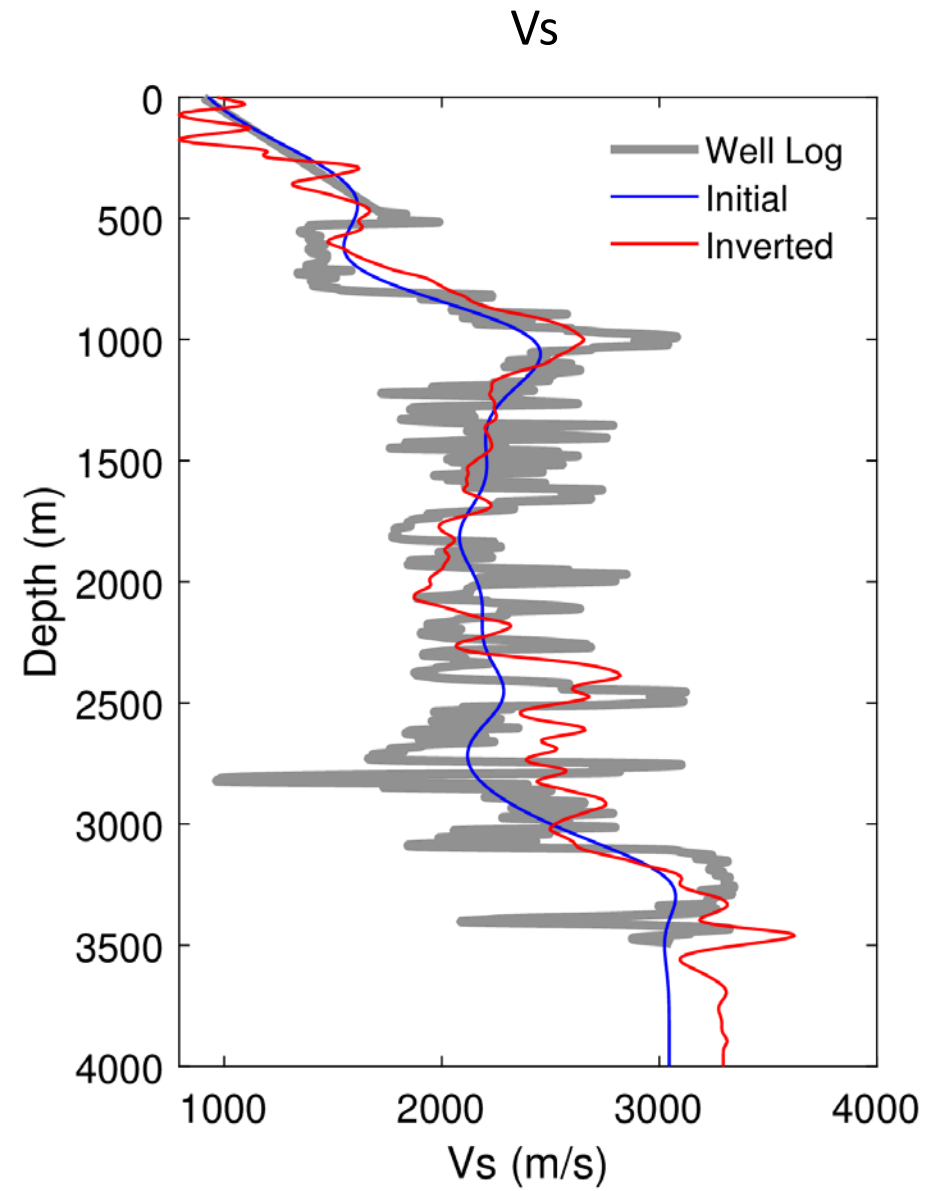
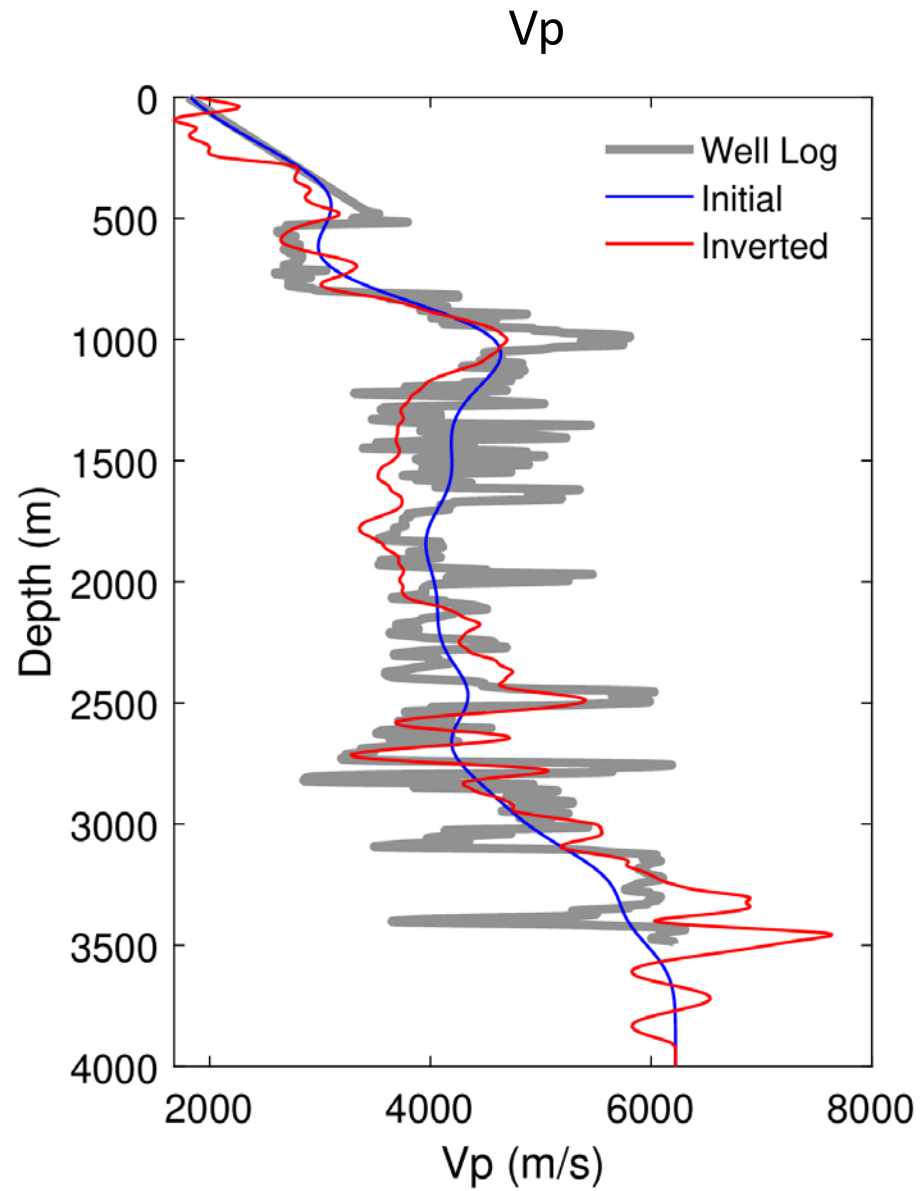
Gabor decon





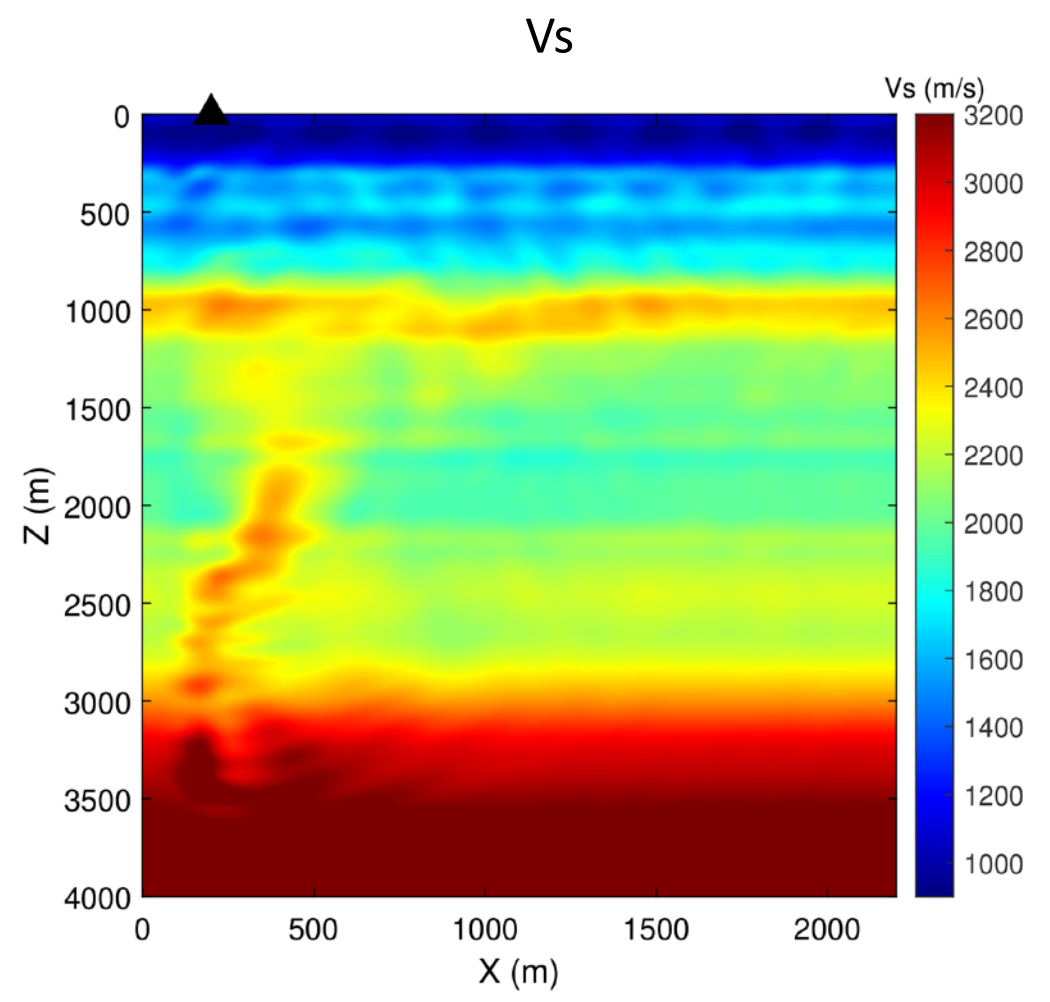
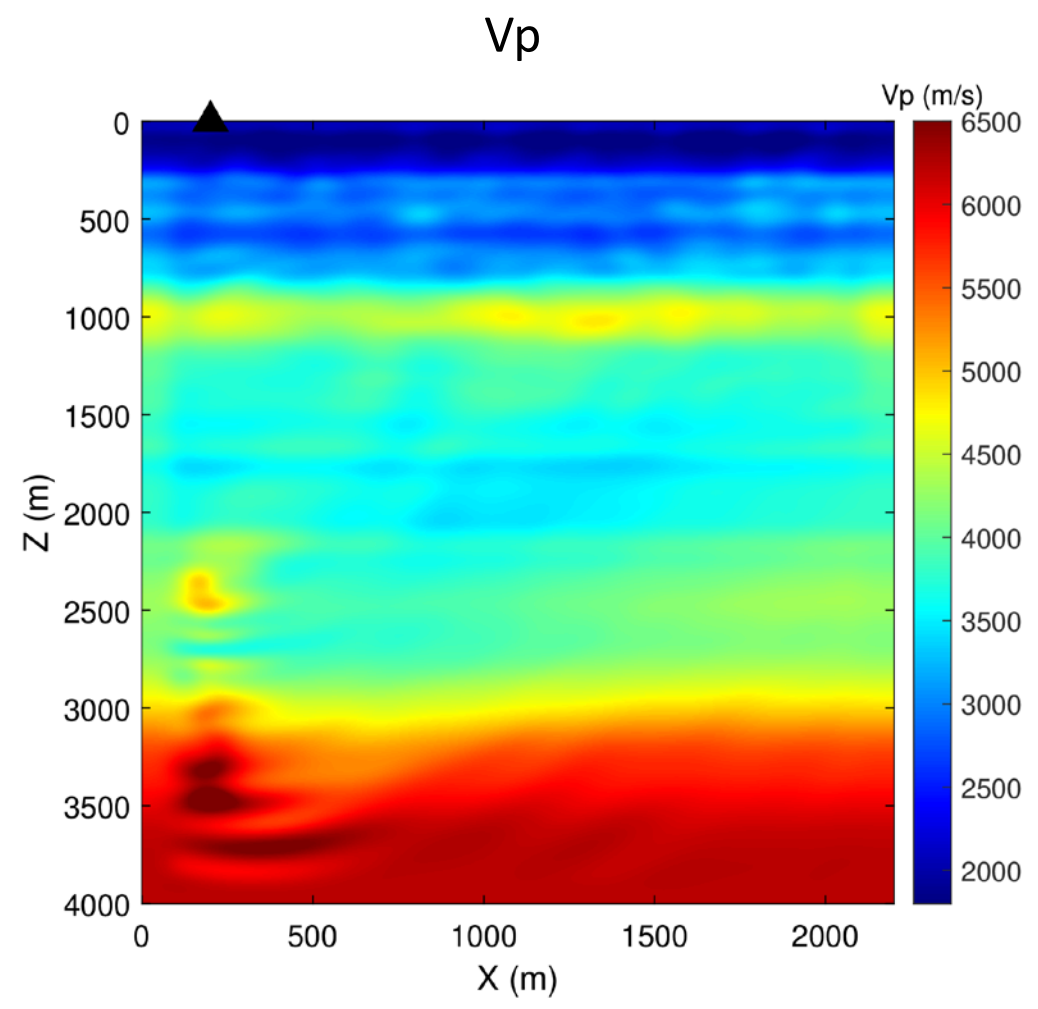
Results for near-offset downgoing-wavefield inversion







FWI results: 2D models



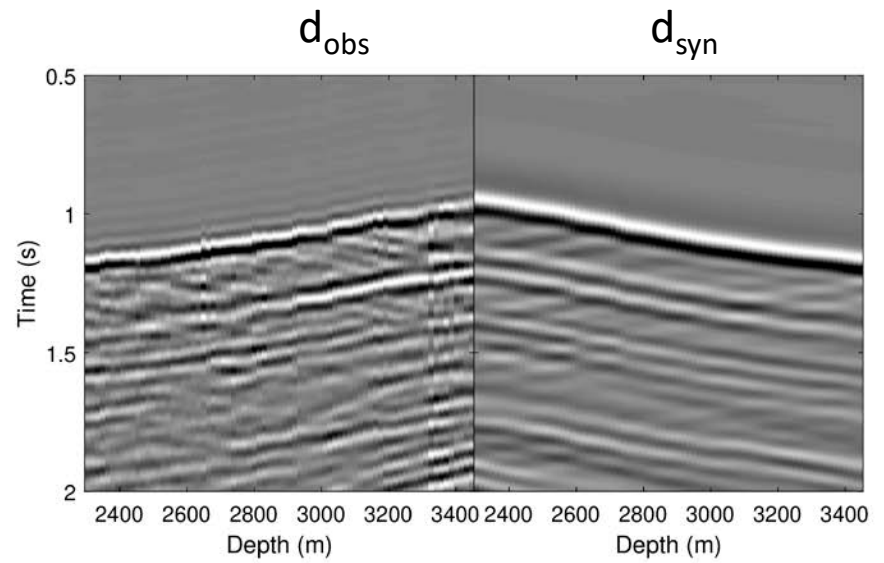
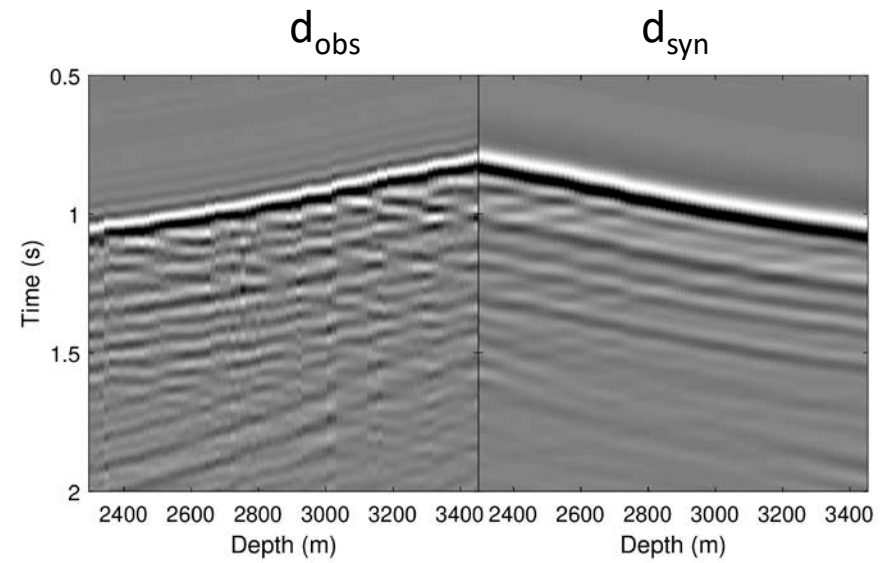


FWI results: modelled vs observed data

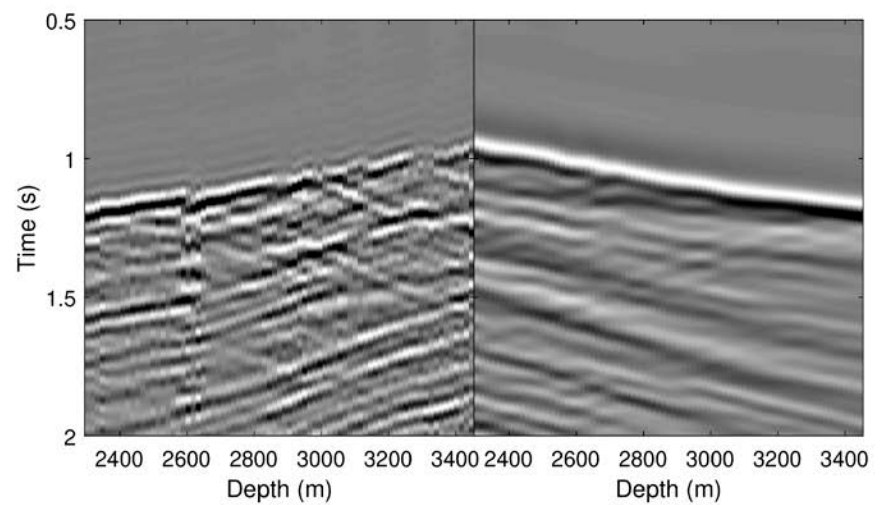
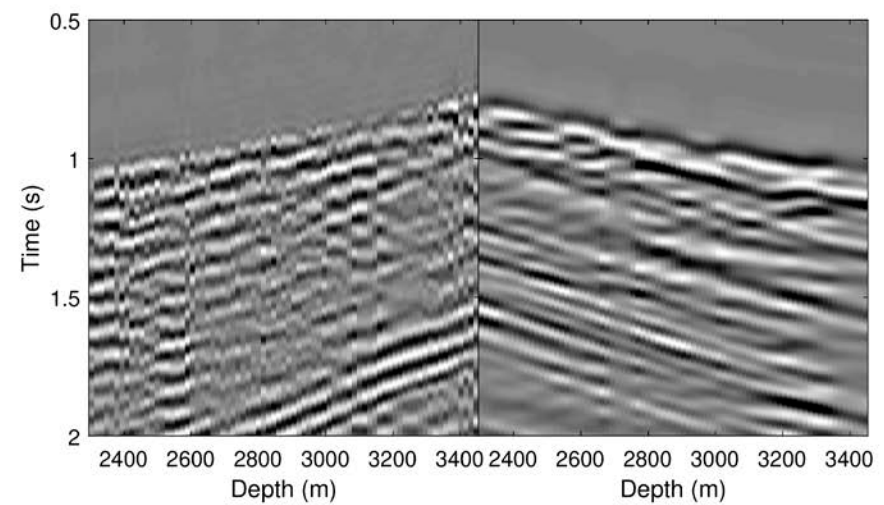
Near-offset data

Far-offset data

Vertical component



Horizontal component





- Despite obtaining a wider frequency band and addressing non-stationarity, the FWI results using Gabor deconvolved data were not optimal.
- A total variation regularization might provide better results when sharp velocity contrasts are present. Initializing the inversion with a blocky model might also help to include multiples energy in the inversion of VSP data.
- Using a deterministic deconvolution attenuated the short-wavelength multiples present in the data facilitating the inversion of the data using a smooth initial velocity and density.
- Multiple plus primary data could be incorporated at later stages for a more complete FWI.
- Also, the deterministic deconvolution revealed S-wave events that were hindered by the multiples providing more data for the inversion.



Acknowledgements

- Devon energy
- Compute Canada
- NSERC (Grant CRDPJ 461179-13)
- Canada First Research Excellence Fund (CFREF)
- CREWES sponsors
- CREWES faculty, staff and students.





Backup Slides



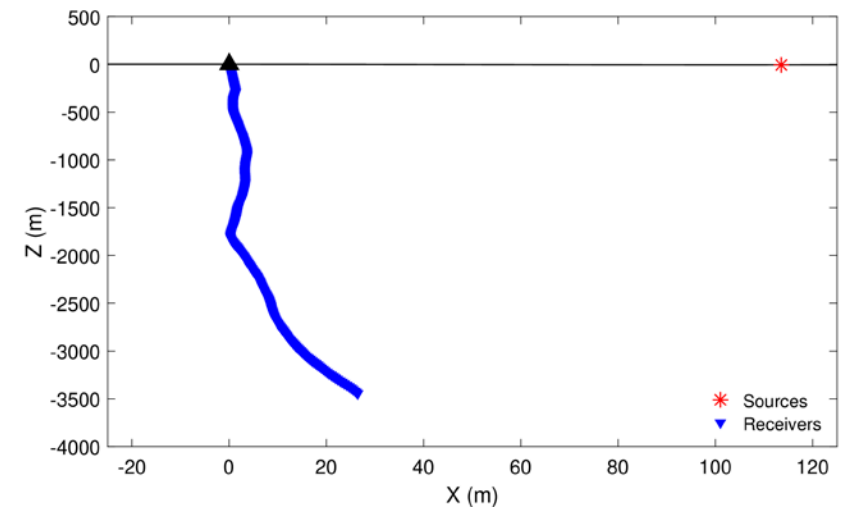
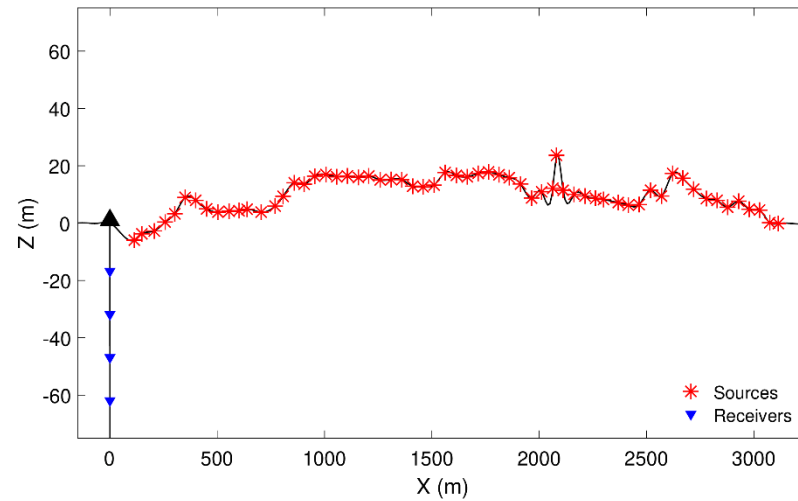
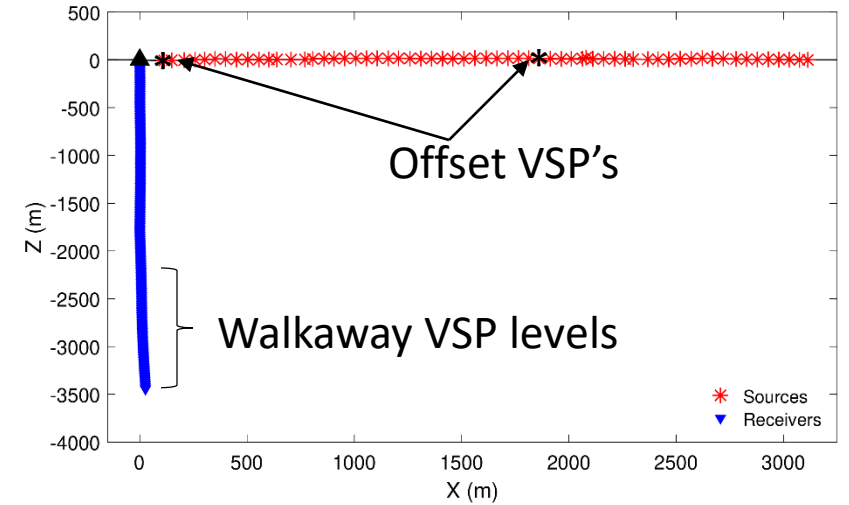
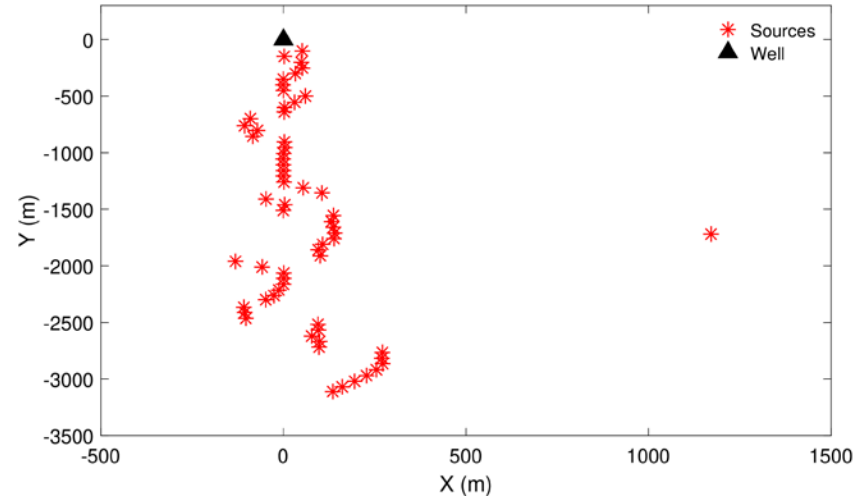
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Receiver parameters:

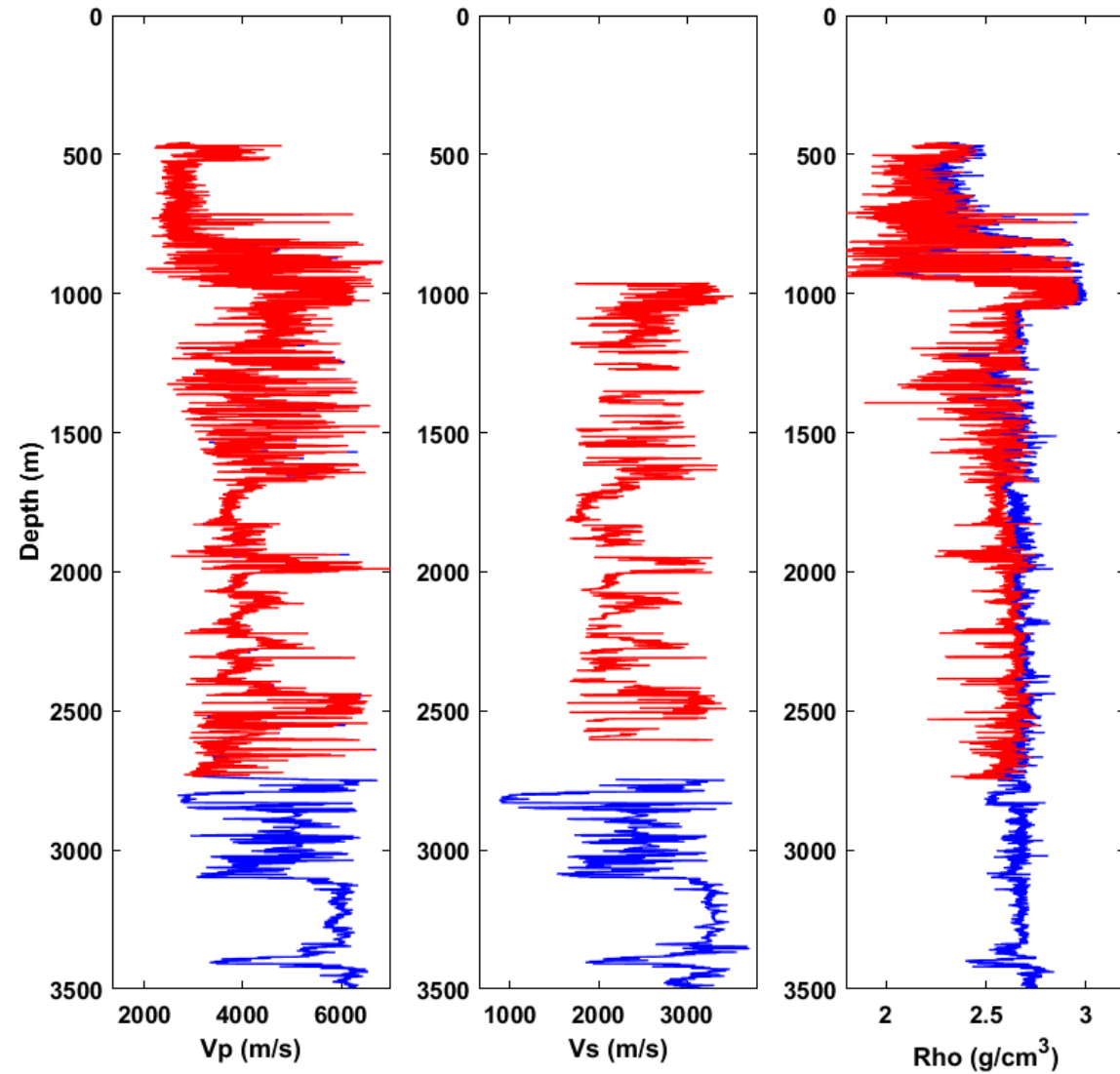
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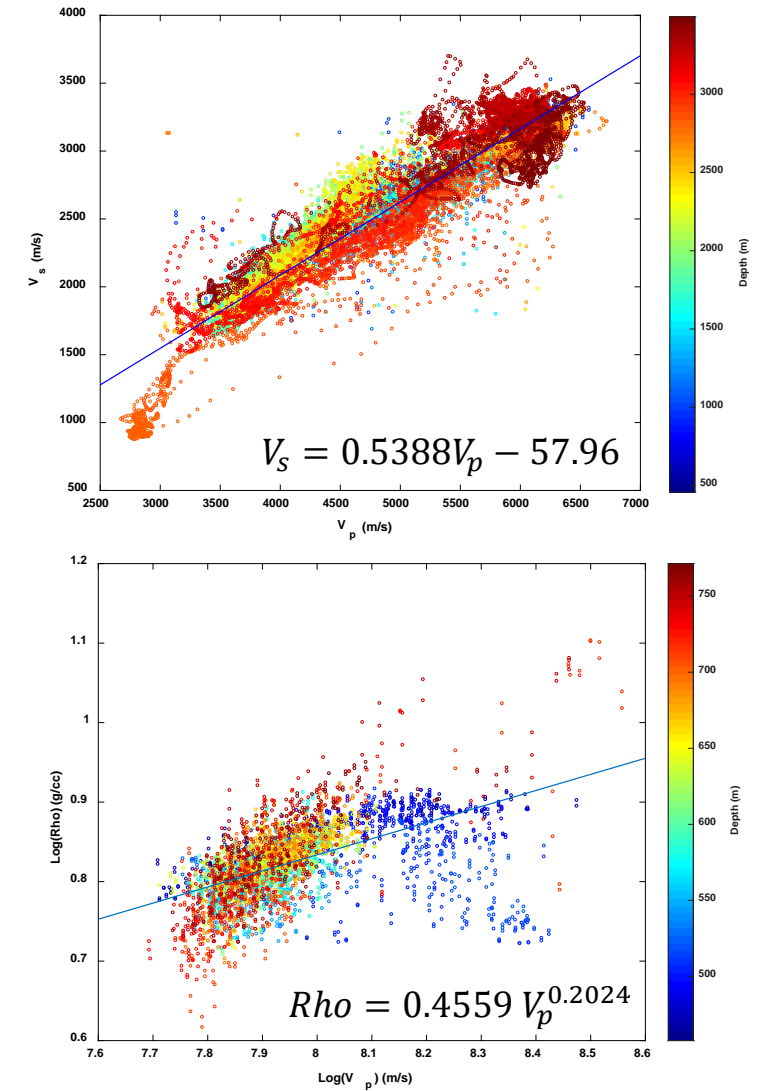


Well data

Raw well logs



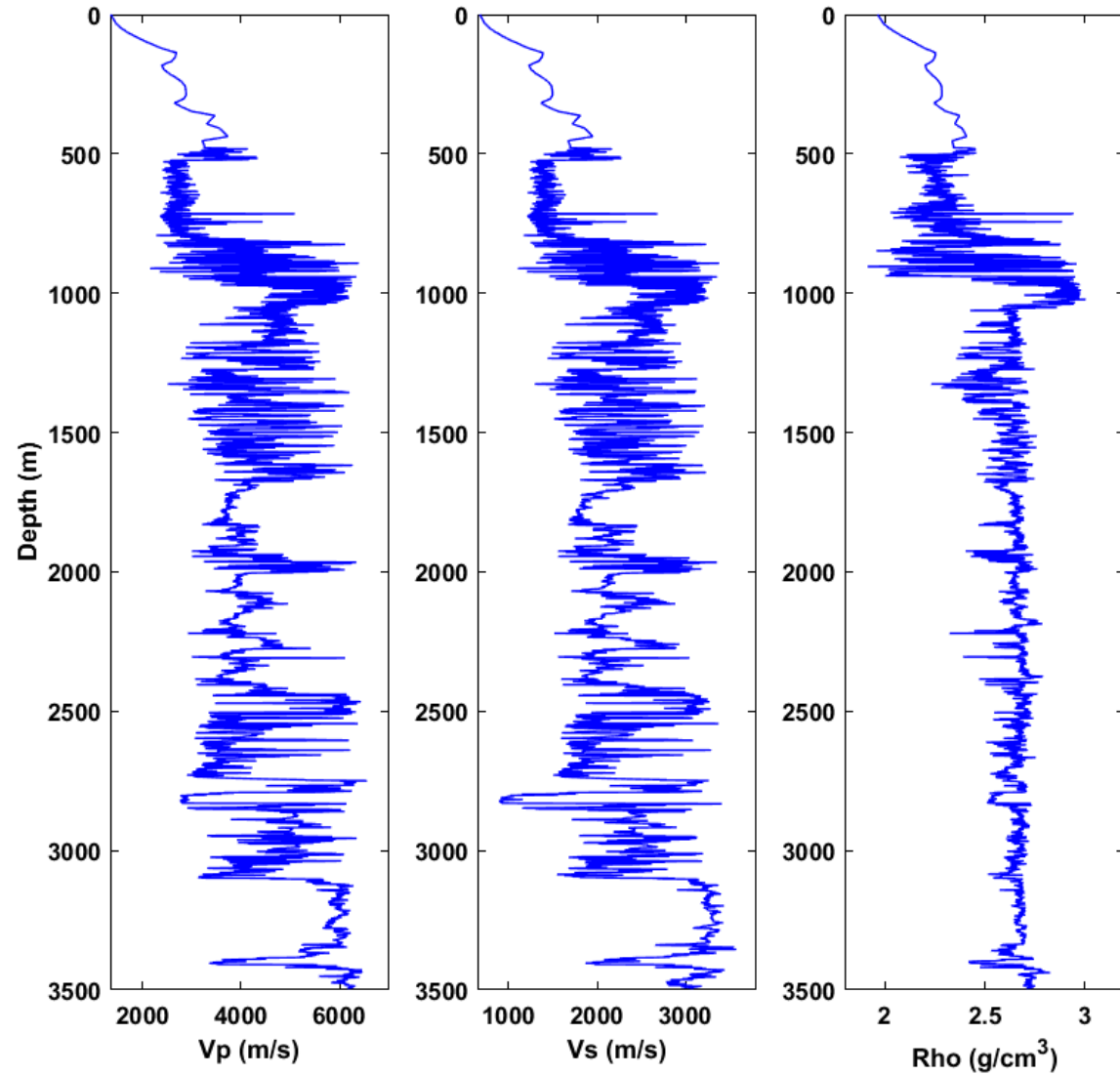
Transformations



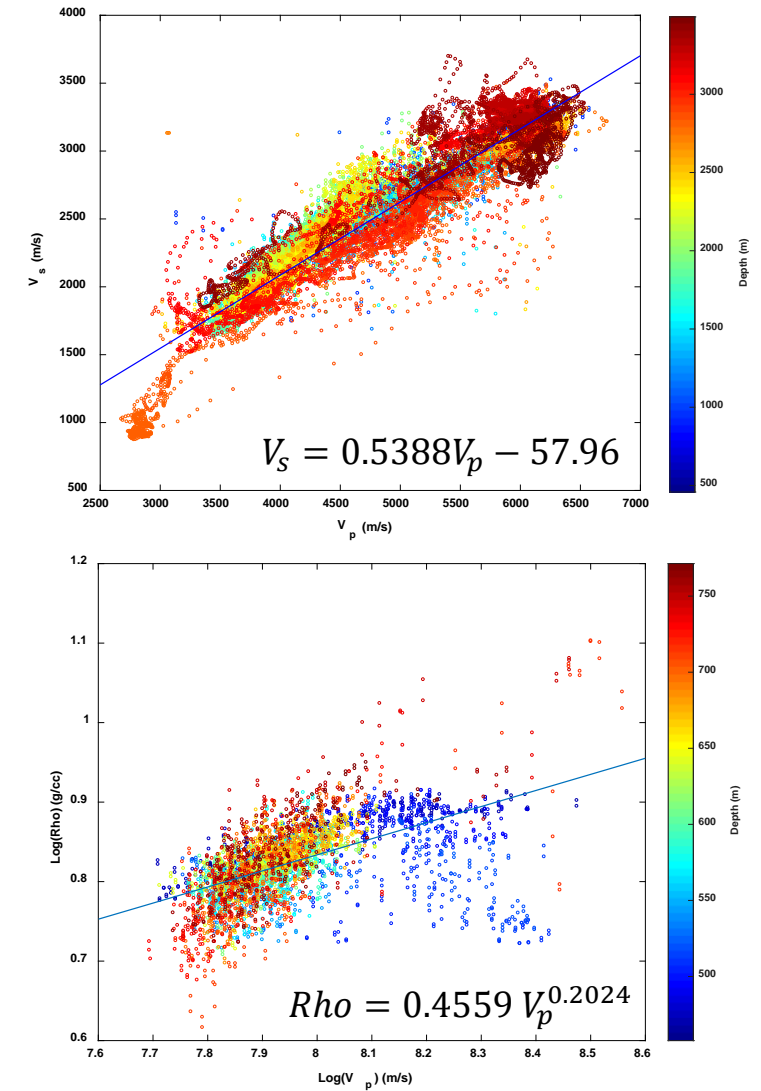


Well data

Edited well logs

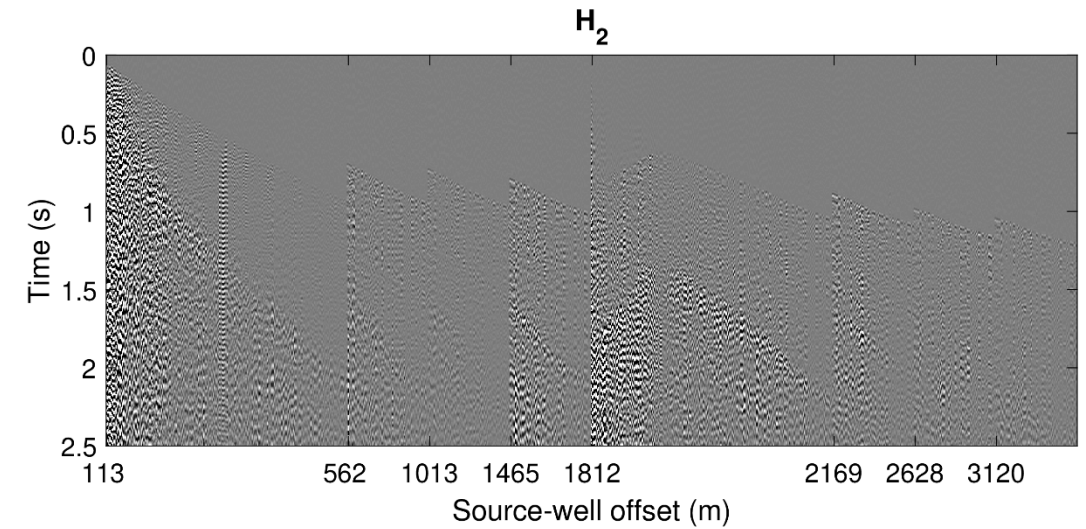
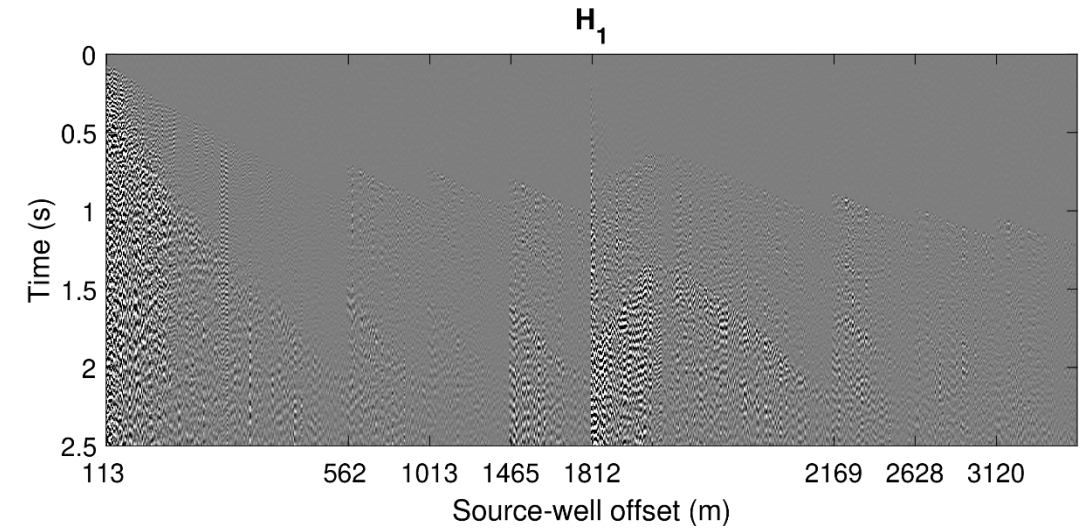
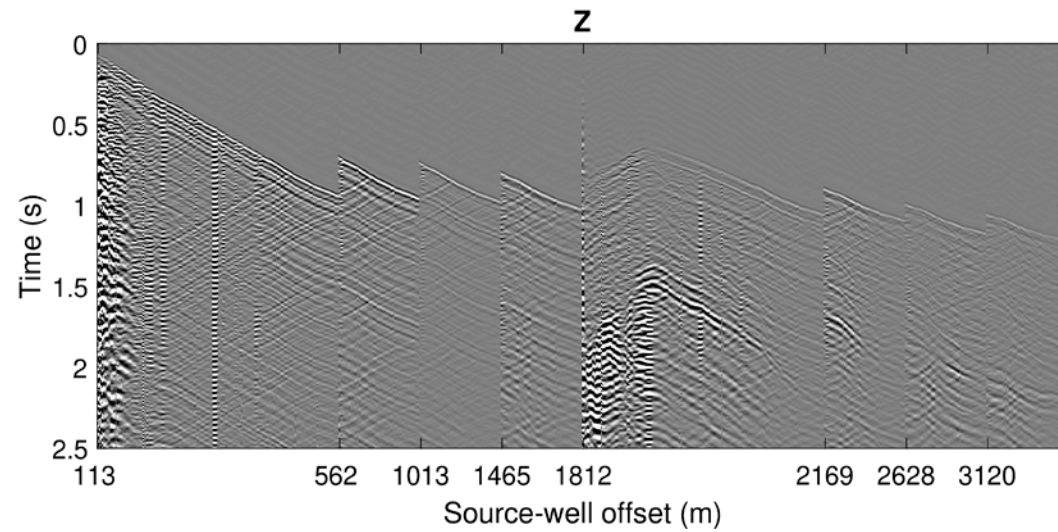


Transformations





Horizontal components rotation

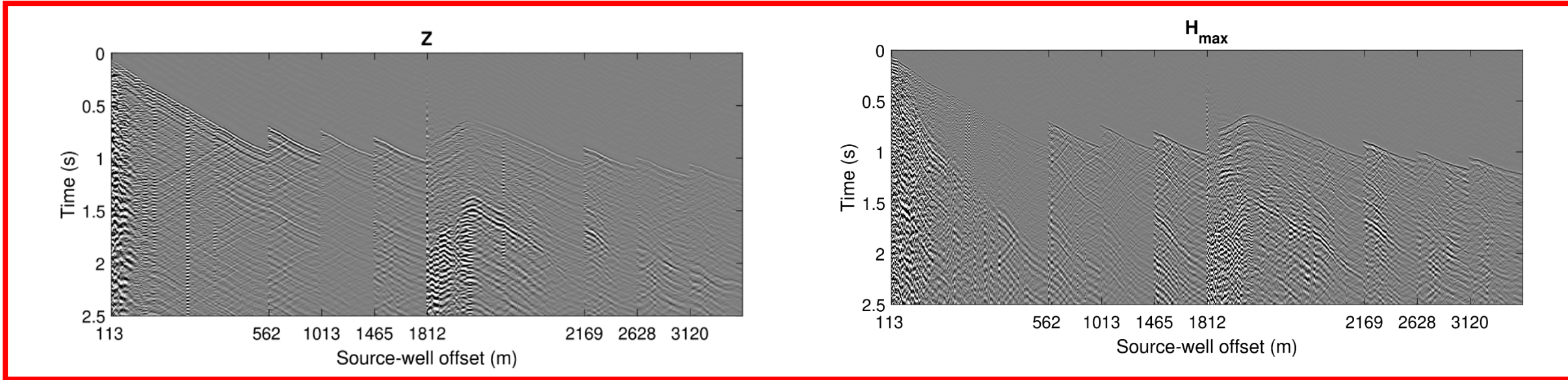


Only the horizontal components were rotated into the source-receiver plane by using hodogram analysis

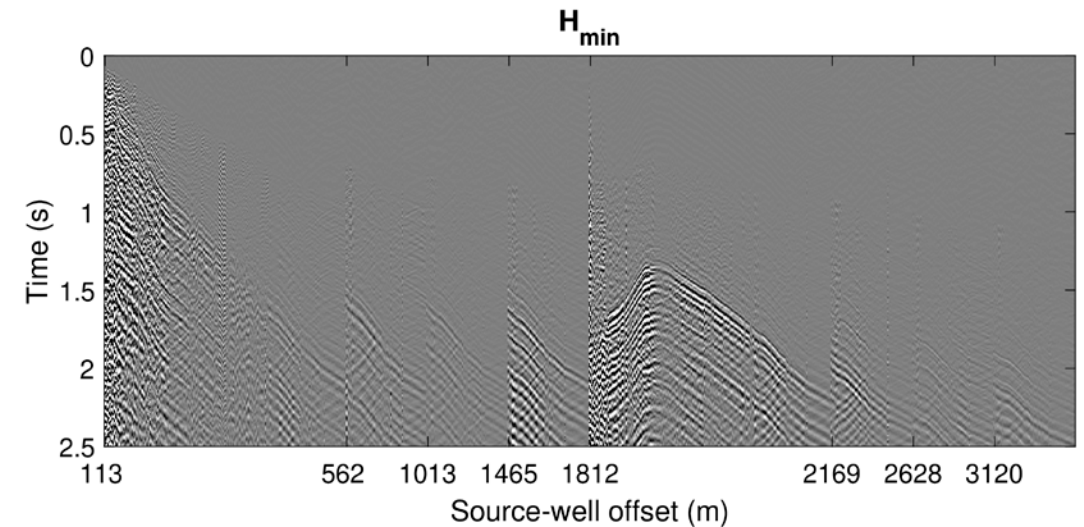


Horizontal components rotation

Used for the inversion



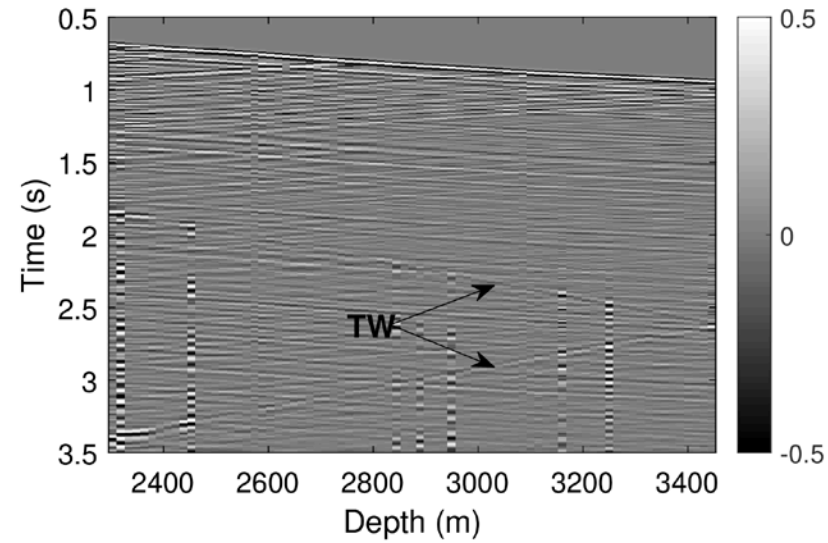
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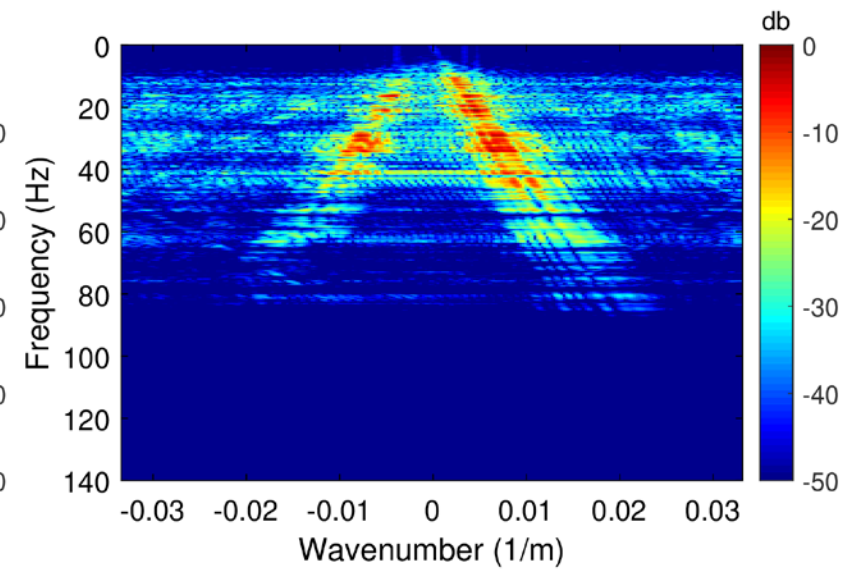
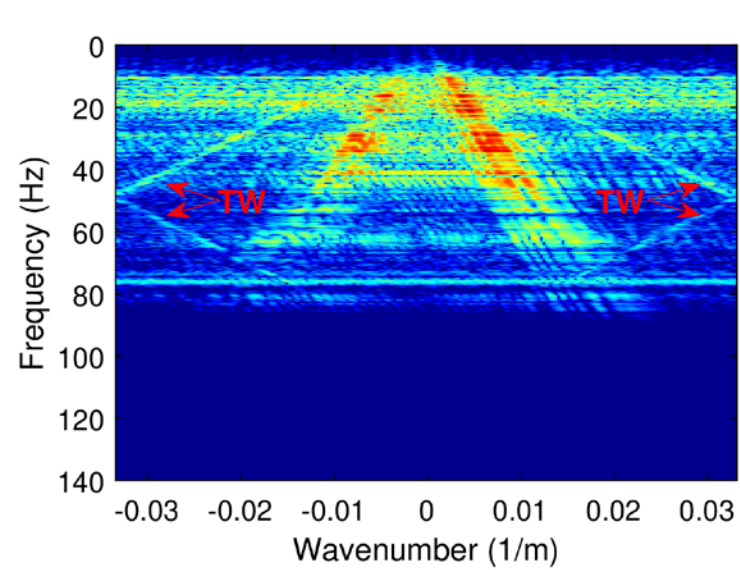
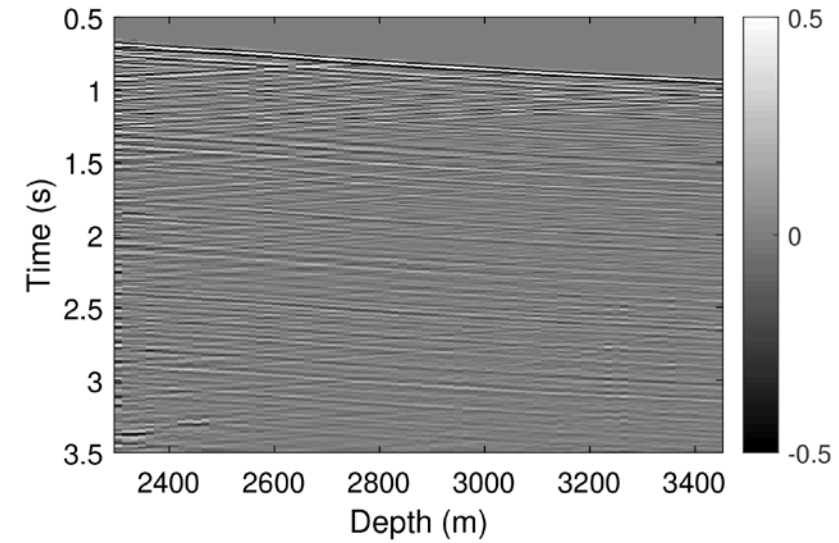


Tube-wave attenuation

Before FX filter



After FX filter

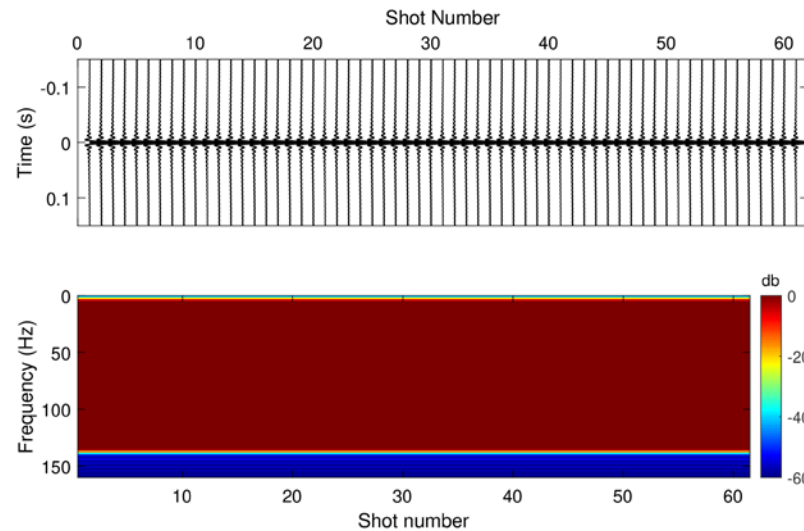




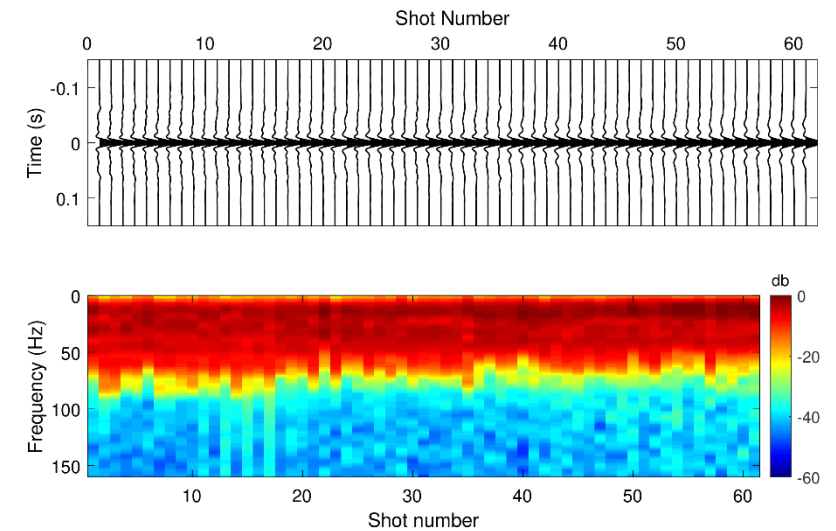
Wavelet extraction

- Zero phase wavelets were extracted using a deconvolution approach.
- Source wavelet amplitude spectra is computed from the inverse of the first arrivals spectra.
- Phase is assumed to be zero.

Sweep derived



Deterministic decon



Gabor decon

