Processing ground roll for the study of near-surface Rayleigh wave dispersion

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Outline

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- Objectives
- Theory
  - Surface wave background
  - Near surface characterization
  - Synthetic modelling
  - Dispersion / Dispersion curves
- Experiment Data Comparison
- Method 1
- Method 2
- Conclusions

Motivations

- The near surface is an unconsolidated, heterogeneous layer, through which seismic waves must travel at least twice
- Recorded ground roll contains information about the difficult to characterize-near-surface
- Understanding the near surface helps to improve imaging
  - Static corrections, preconditioning FWI

Objectives

- Generate dispersion spectra from synthetic, exploration scale seismic surveys
- Find the cause of noise in dispersion curves
- Test interpolation as a method to reduce noise
- Test other filtering to reduce noise

Find the most effective method of reducing dispersion spectrum noise, generated from sparsely sampled shot records

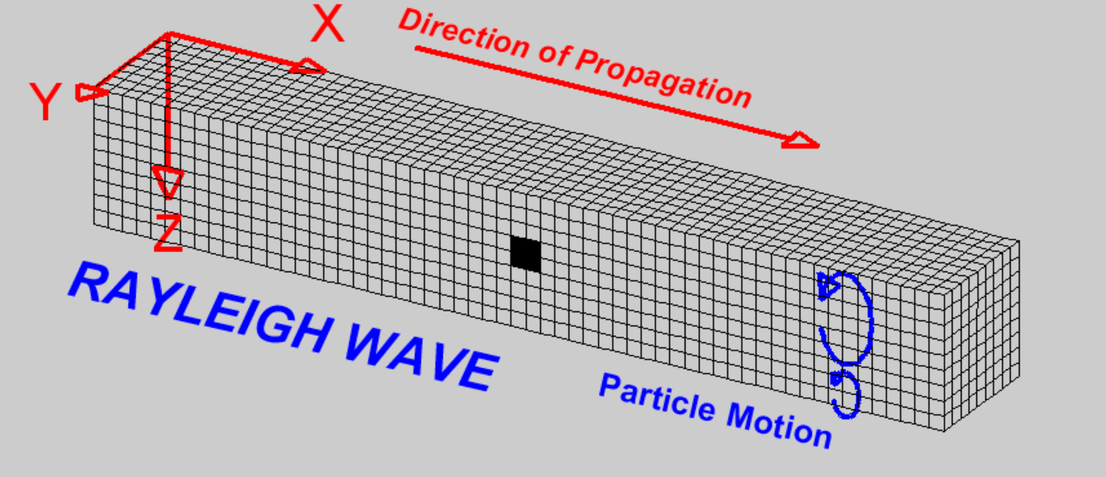
Surface Waves

- Surface waves arise from the presence of a free surface (air-rock boundary).
- Travel along this surface, confined within the near surface layers.
- Cylindrical propagation character
  - Less geometric attenuation
- Smaller distances travelled relative to body waves
- Attenuate rapidly with depth, less rapidly in propagation direction

- Dispersive
  - Different frequency components travel at different velocities

Rayleigh Waves

- Incident compressional wave partitions into
  - Reflected and transmitted P and SV waves
- Coupled P-SV retrograde elliptical particle motion
- $> \frac{2}{3}$ of compressional source energy takes Rayleigh wave form
- Are ground roll in seismic recordings
  - Usually filtered out and discarded

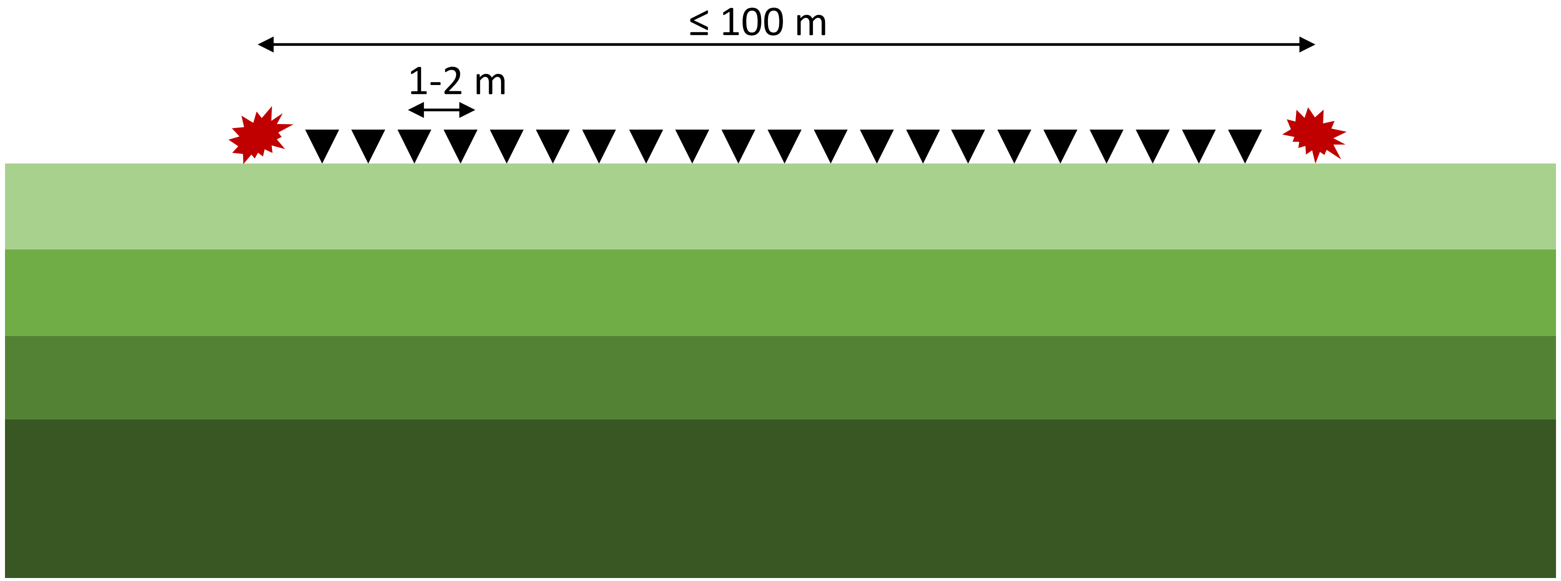


http://web.ics.purdue.edu/~braile/edumod/waves/Rwave.htm

Multichannel Analysis of Surface Waves (MASW)

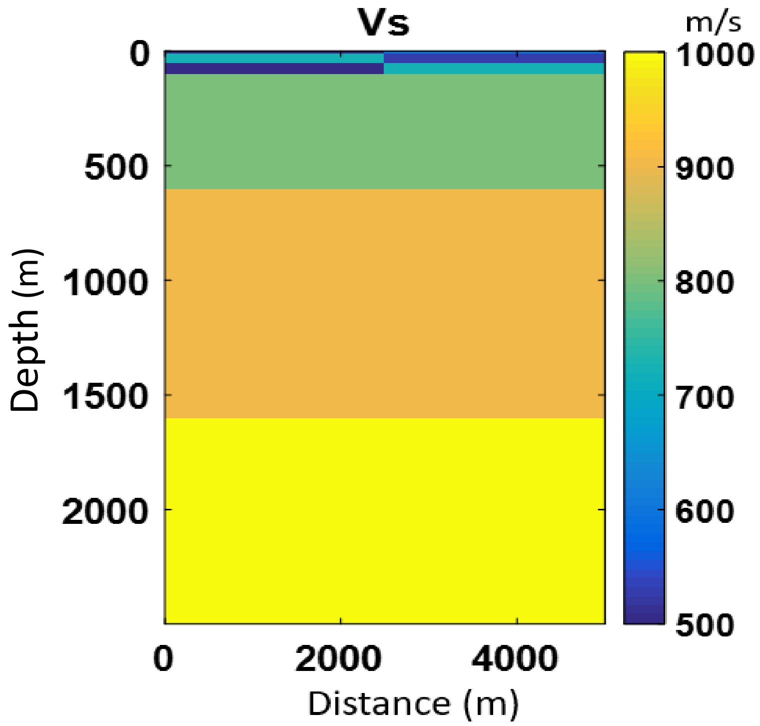
- Uses a spread of low frequency receivers
- Swept frequency or explosive source (many frequencies simultaneously)
- Two off-end shots – Detects lateral heterogeneity

- Similar to reflection seismic surveys

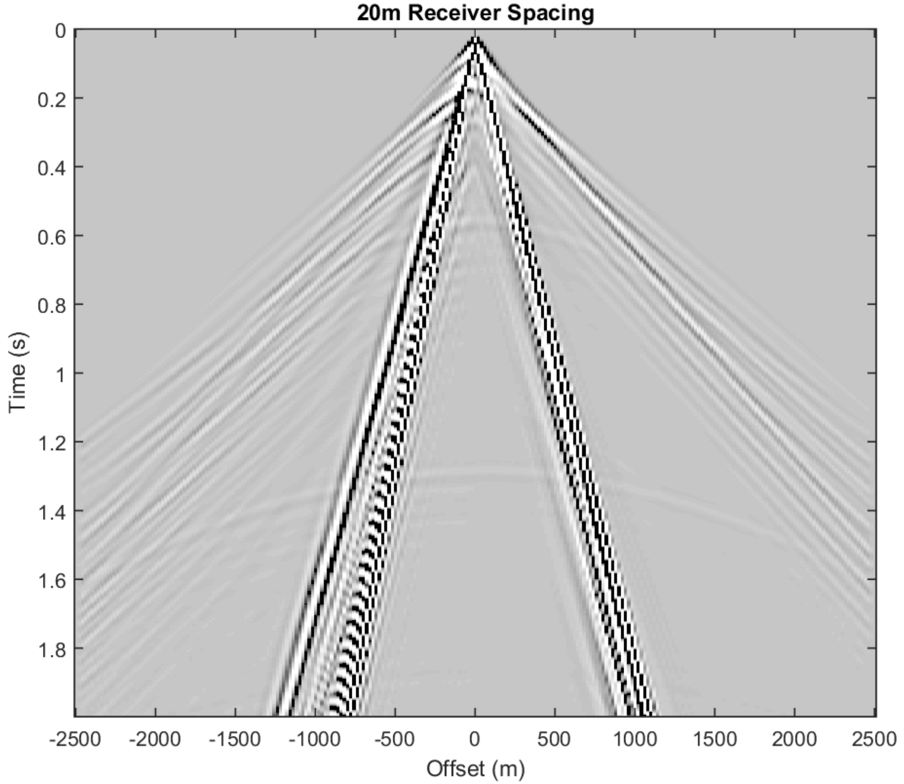


Forward Modelling Methods

- Vp, Vs, and ρ models built in Matlab
  - 5000m wide, 2500m deep
  - Near surface layers within top 100m
  - 2 reflectors at 510m and 1510m depth



Models input to SOFI2D
- 2D finite difference elastic wavefield modelling
- Receivers from 100m to 4900m, at 5m depth
  20m and 10m spacing
- Explosive point source at x=2500m, z=5m
- Free surface at z=0



Dispersion / Dispersion Spectra

Dispersion Curve Generation:

Tau-p transform from *d(x, t)* to *d′(p, τ)*

↓

Fourier transform over *τ*, producing *d′′(p, ω)*

↓

Compute the amplitude spectrum

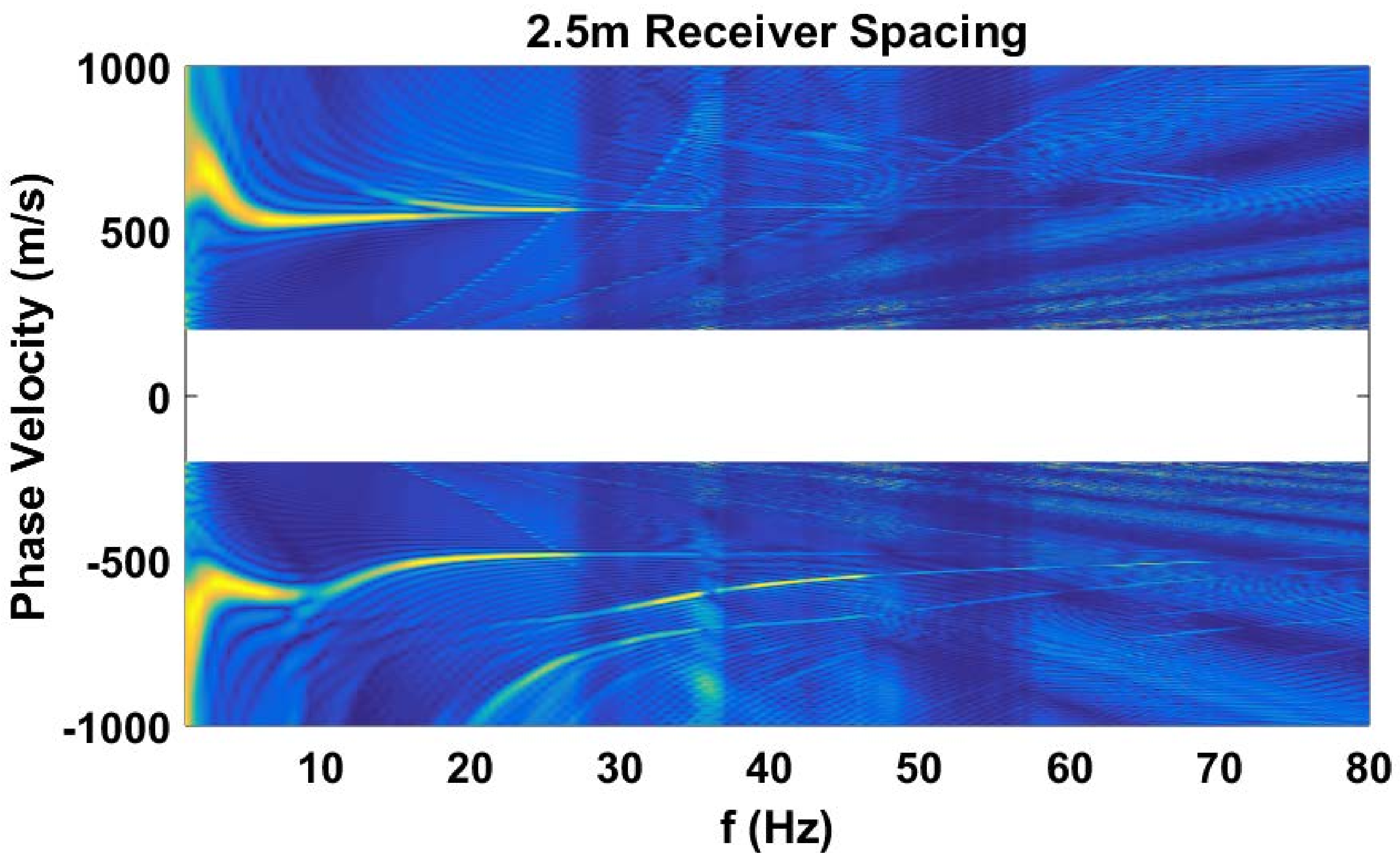
↓

Map slowness p to velocity

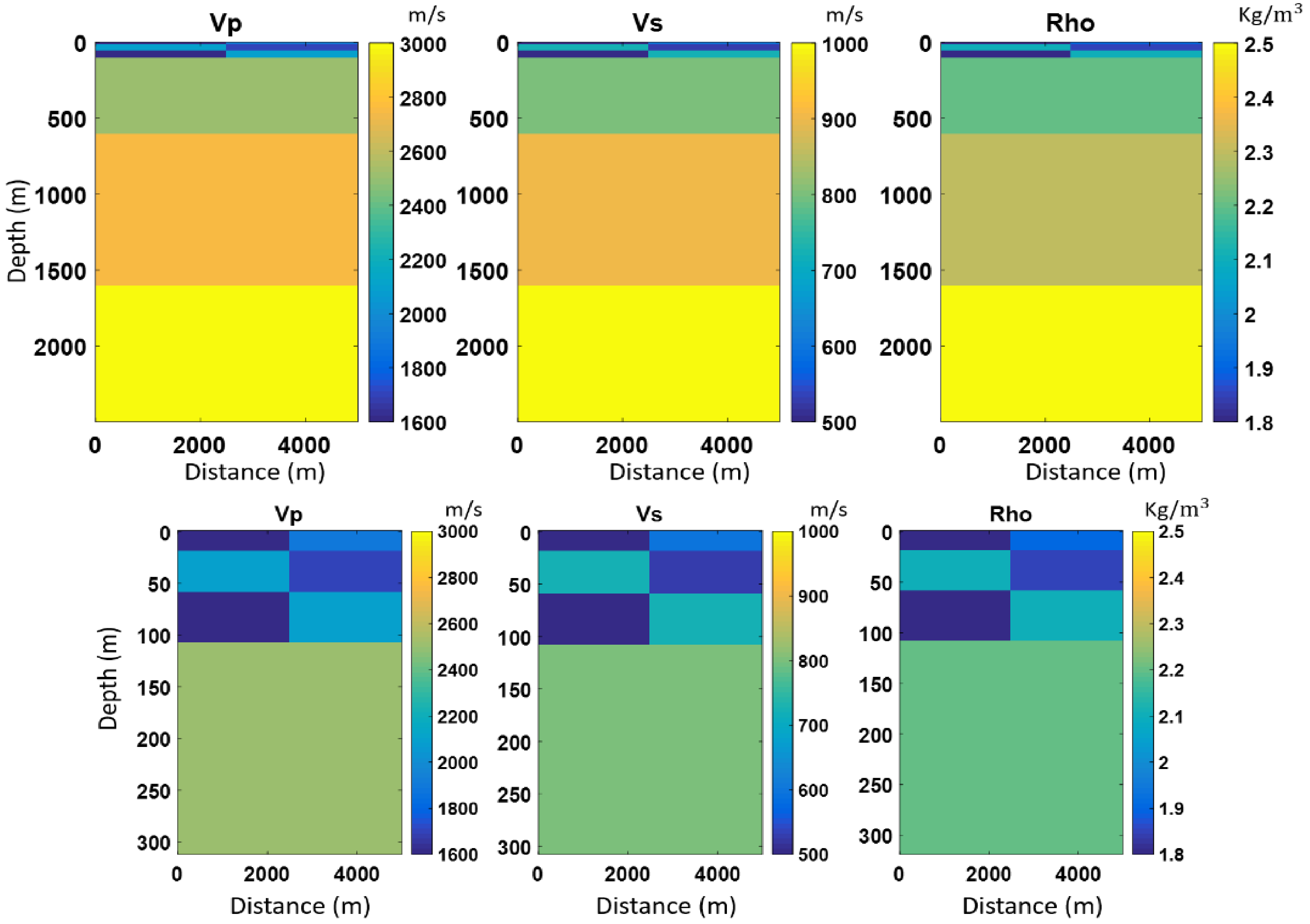
↓

Plot phase velocity versus frequency

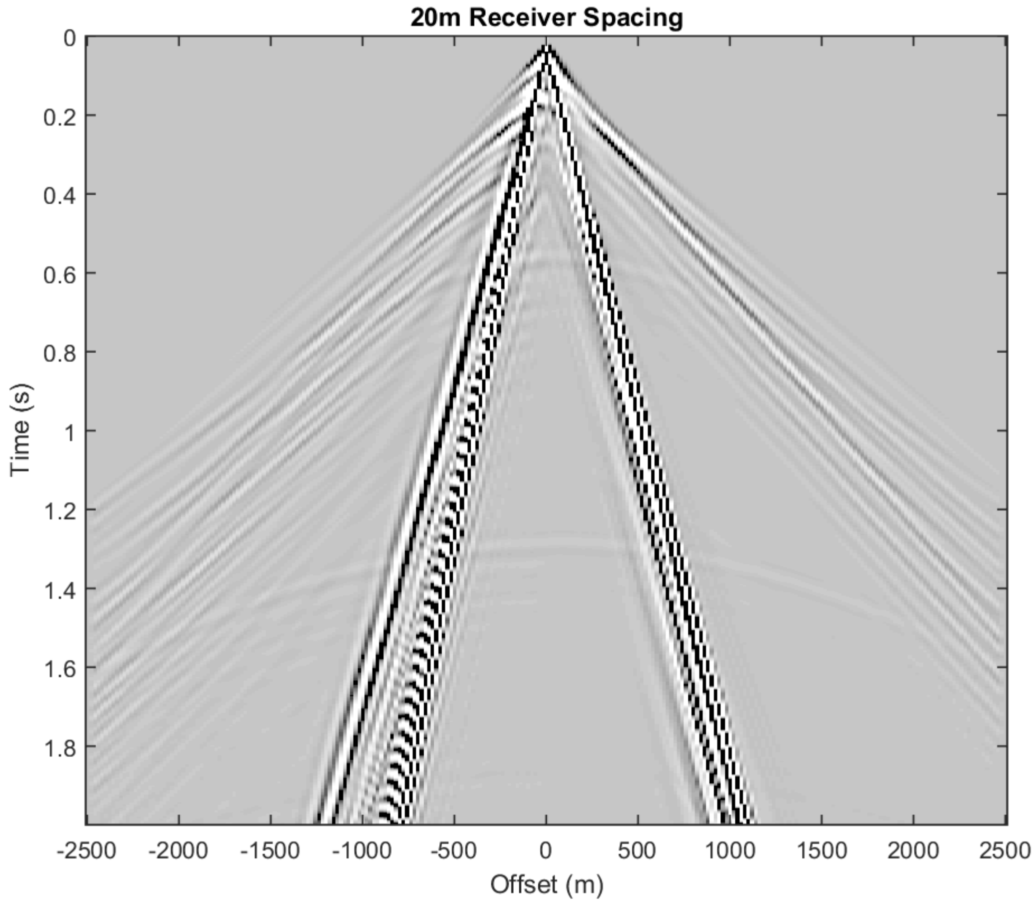
$$F(\tau, p) = \sum_{i=1}^{n} F(x_i, \tau + p x_i)$$

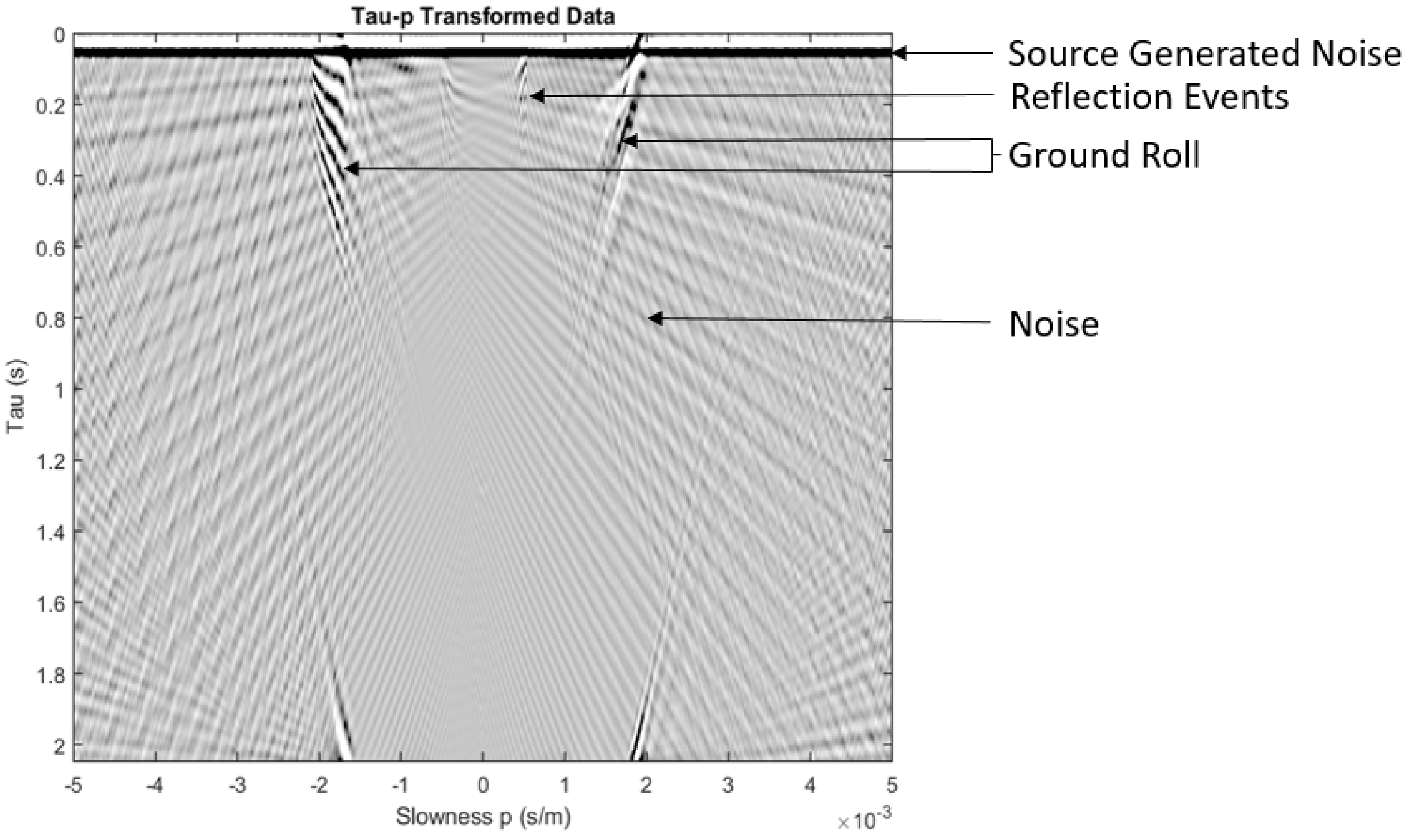


Geologic Model

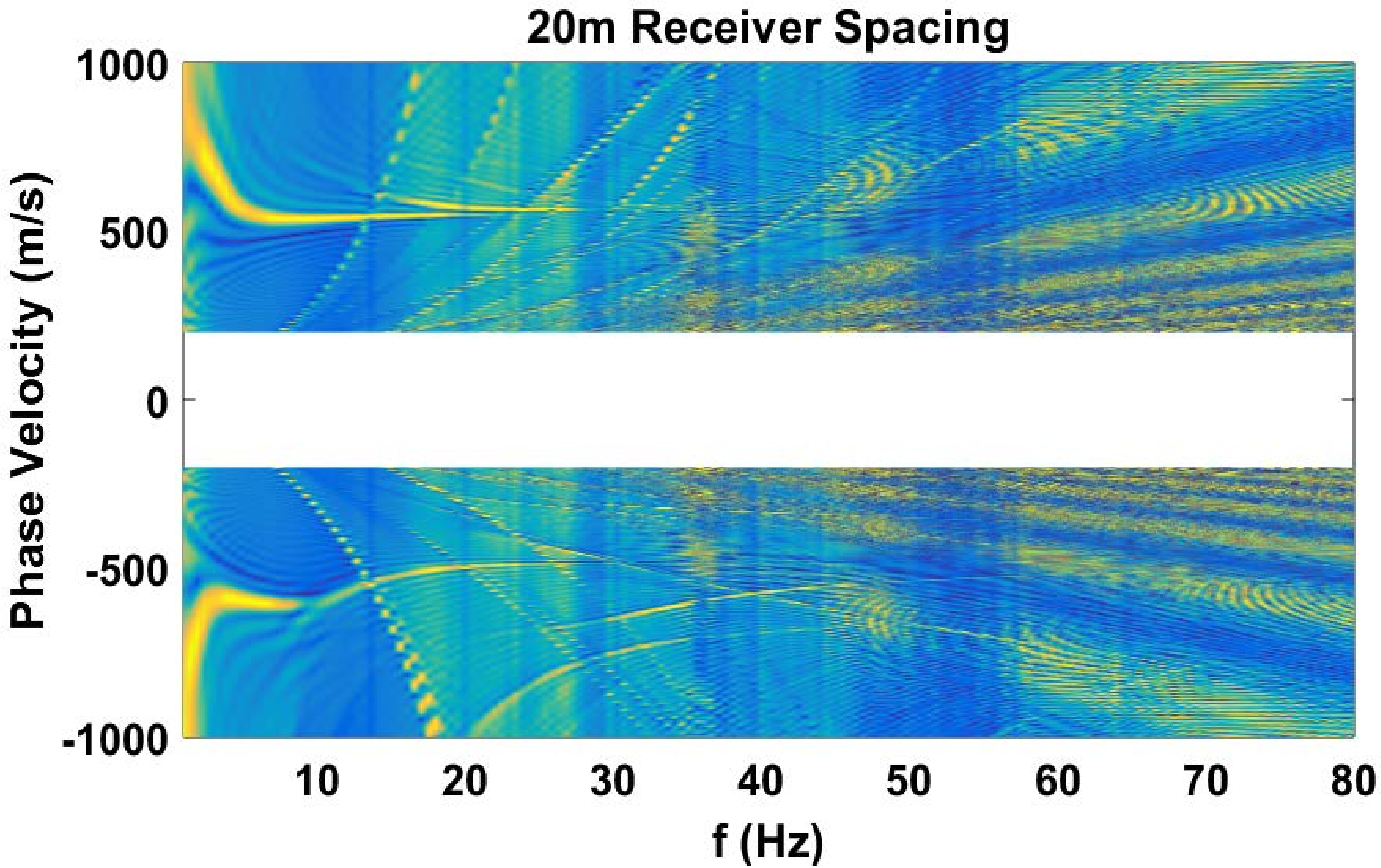


20m Receiver Spacing

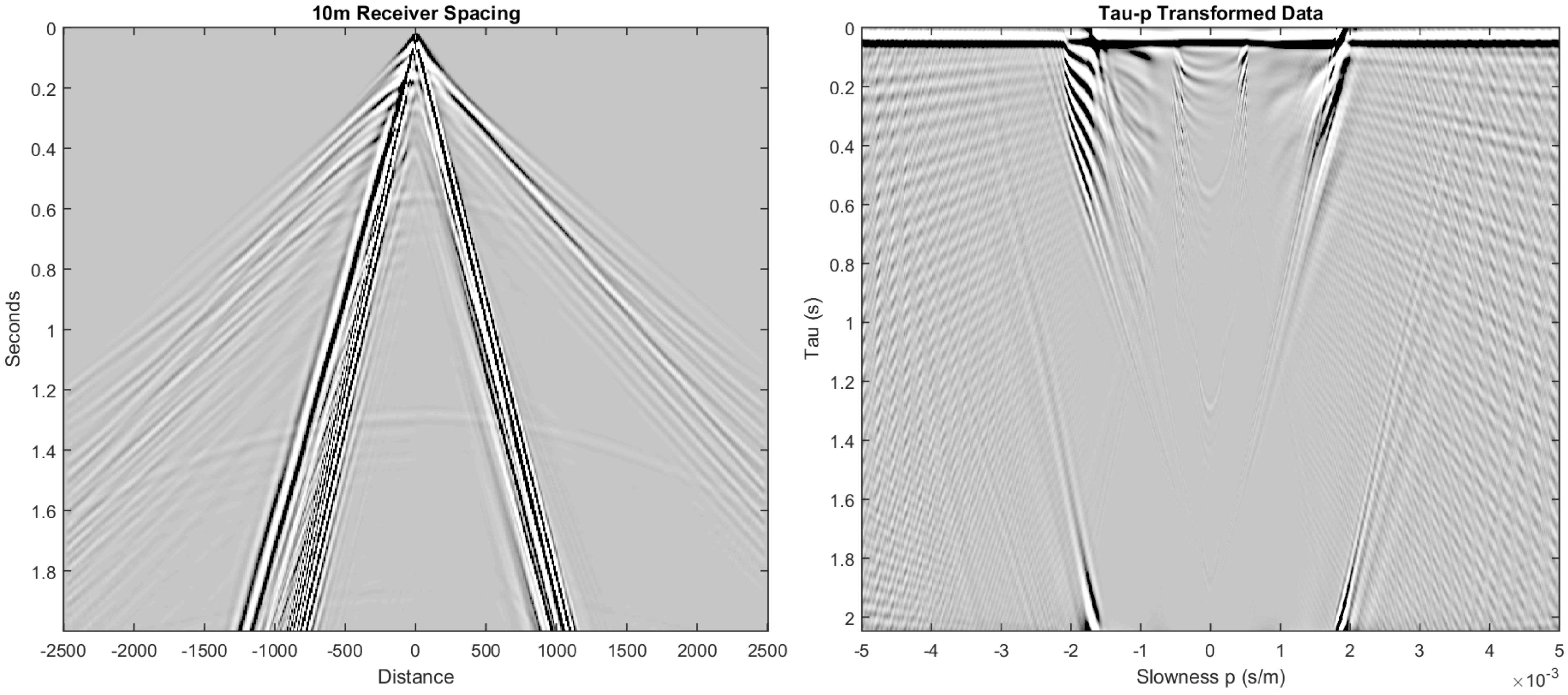




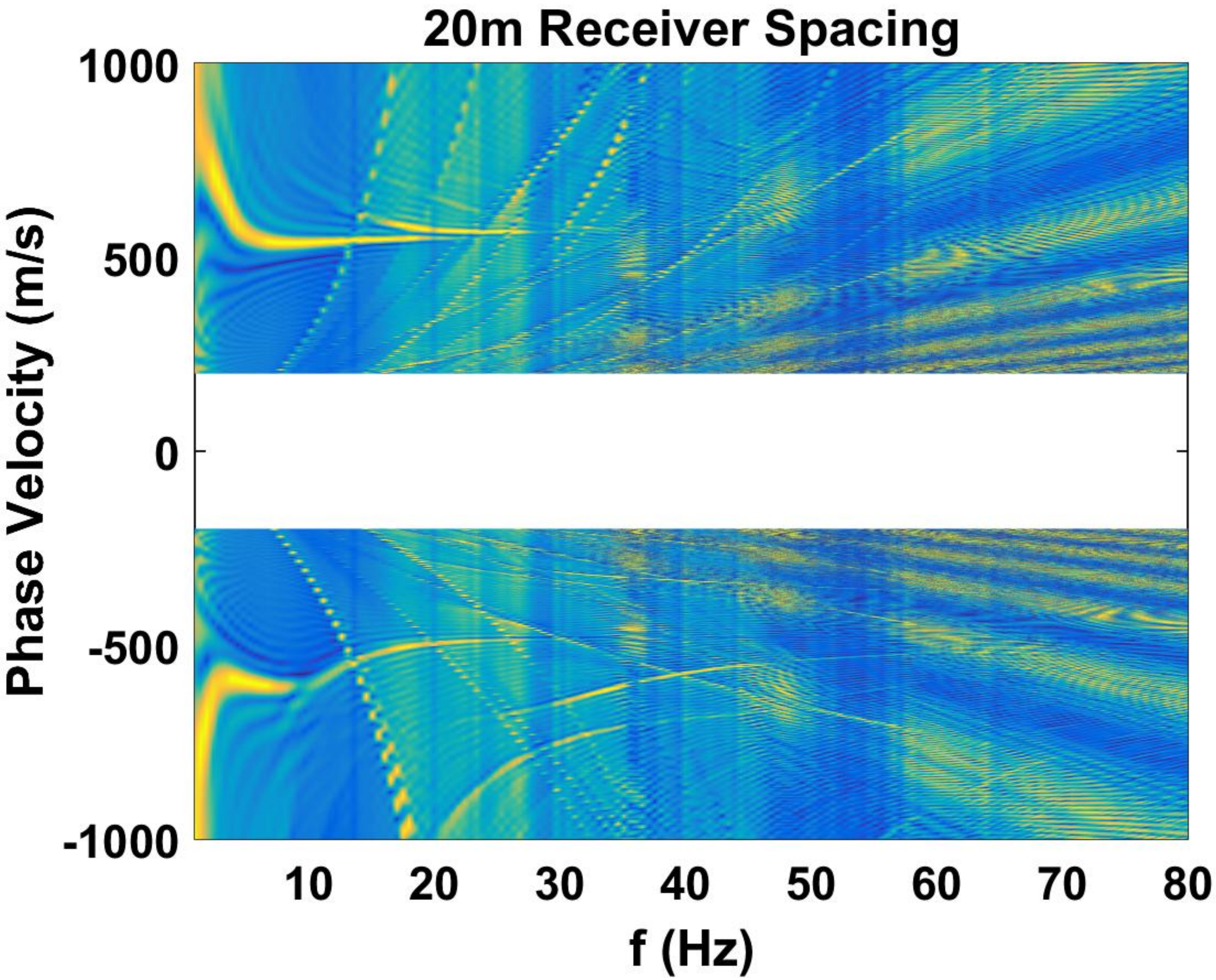
20m Dispersion Spectrum



10m Receiver Spacing



10m Dispersion Spectrum



Method 1 – Filtering Followed by Interpolation

Filtering followed by interpolation

Mute of refractions and direct arrivals

↓

FK filtering to reduce reflections

↓

LNMO Correction

↓

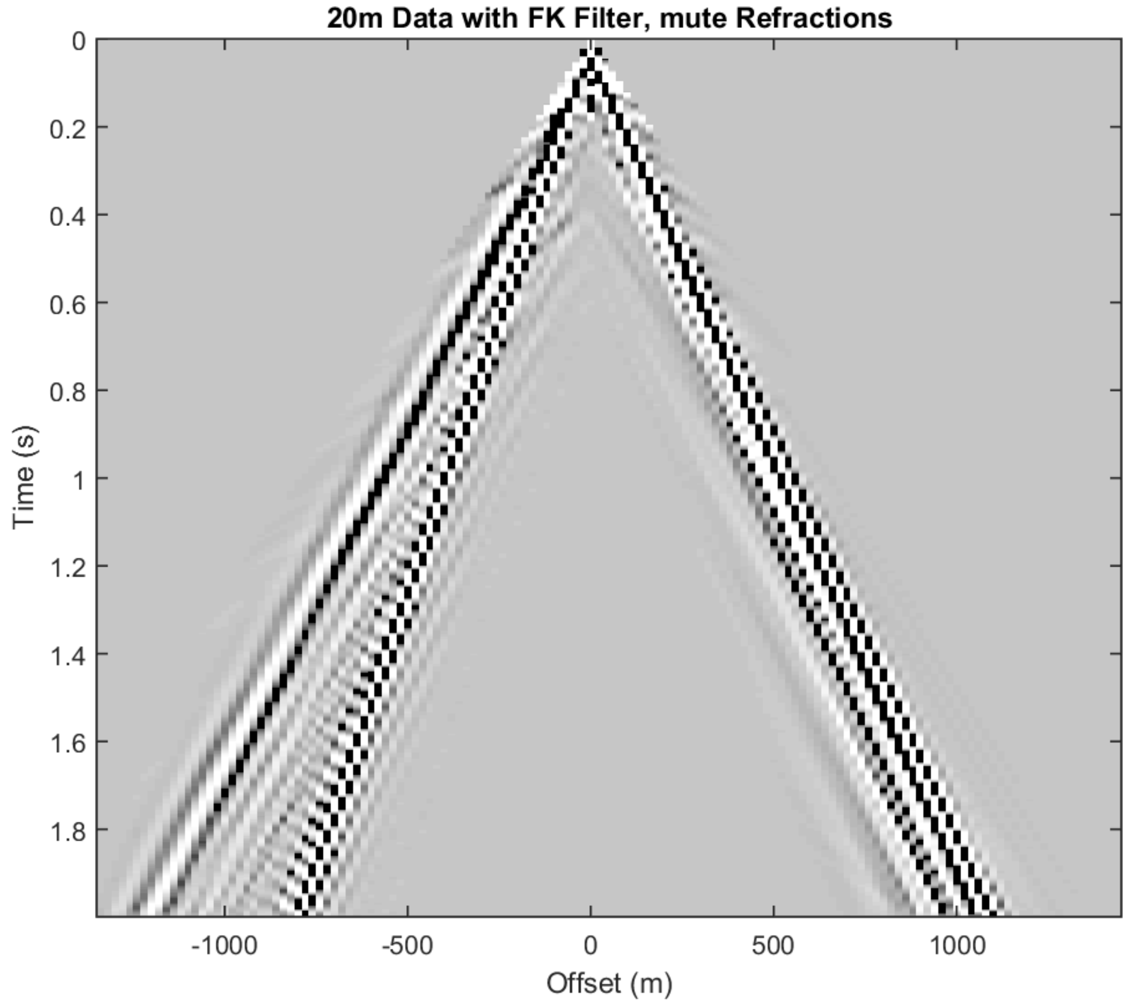
2D Interpolation

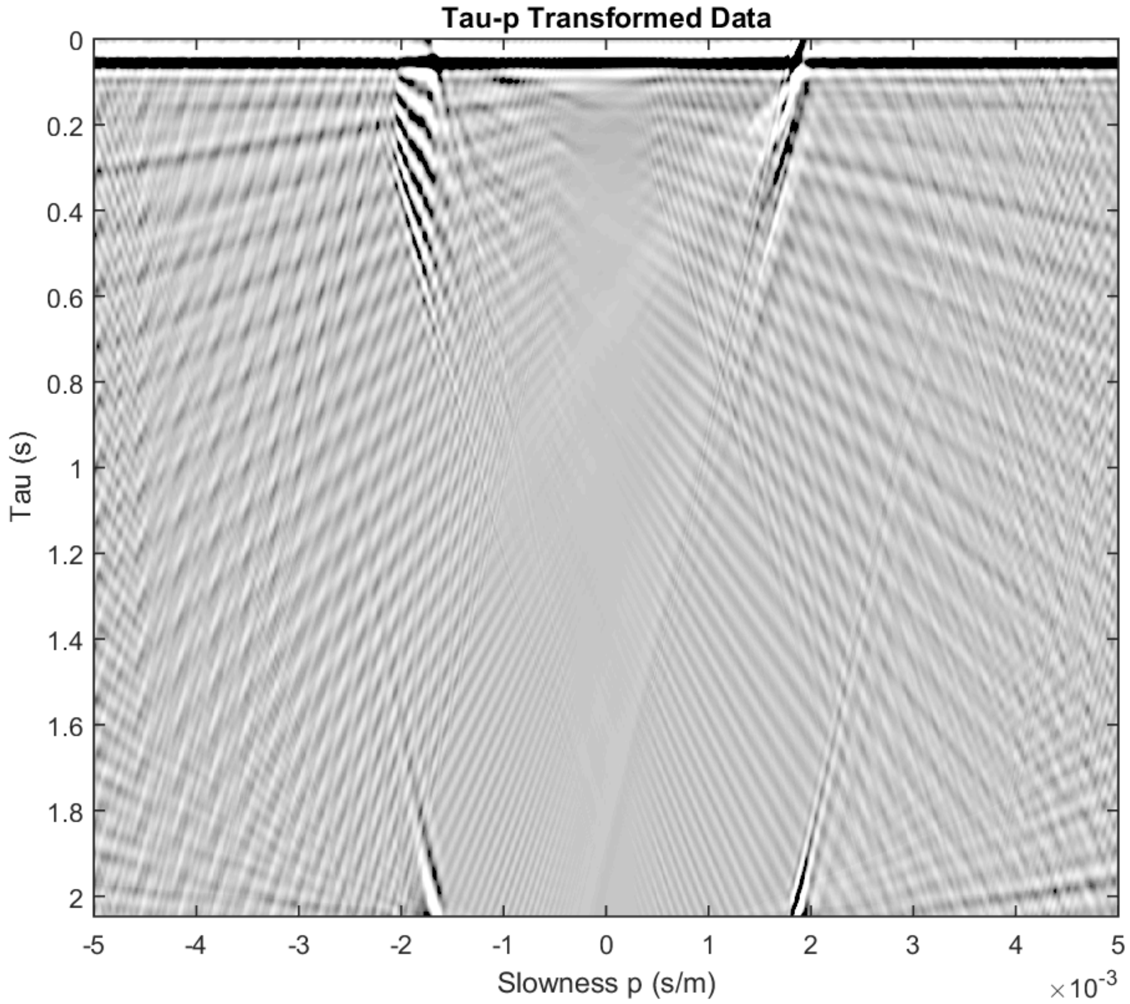
↓

Reverse LNMO Correction

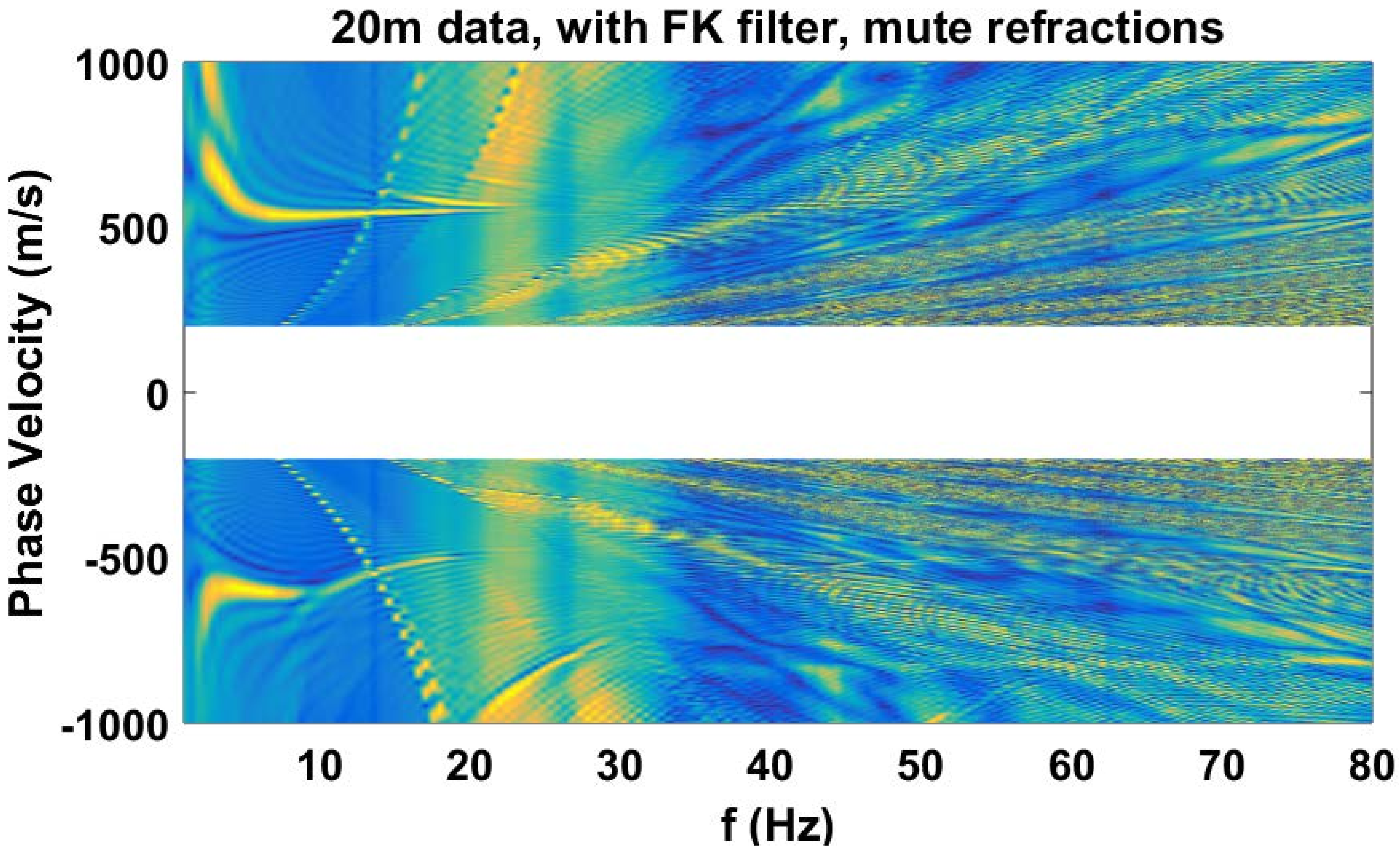
Method 1 – Filtering

FK Filtered and Muted Refractions

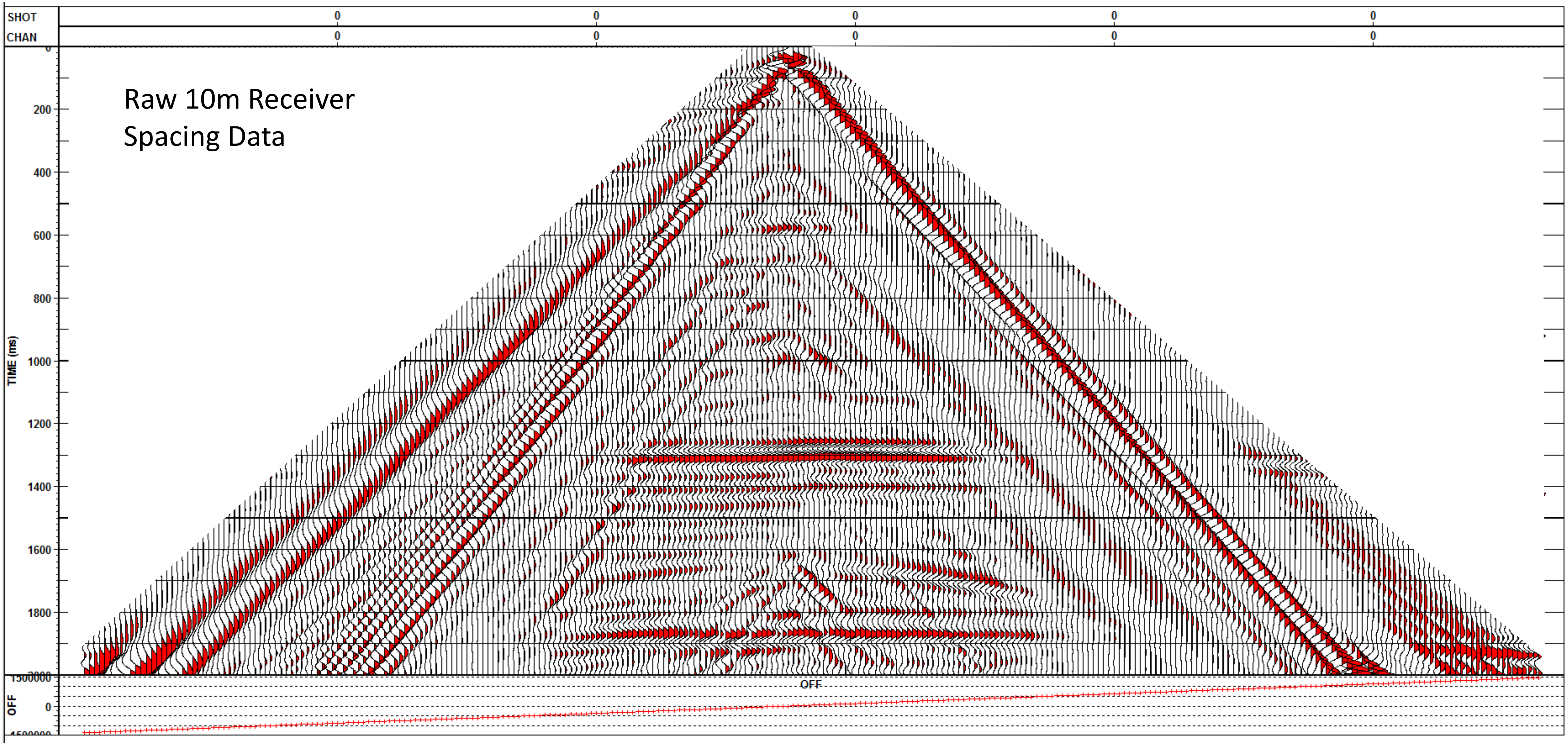




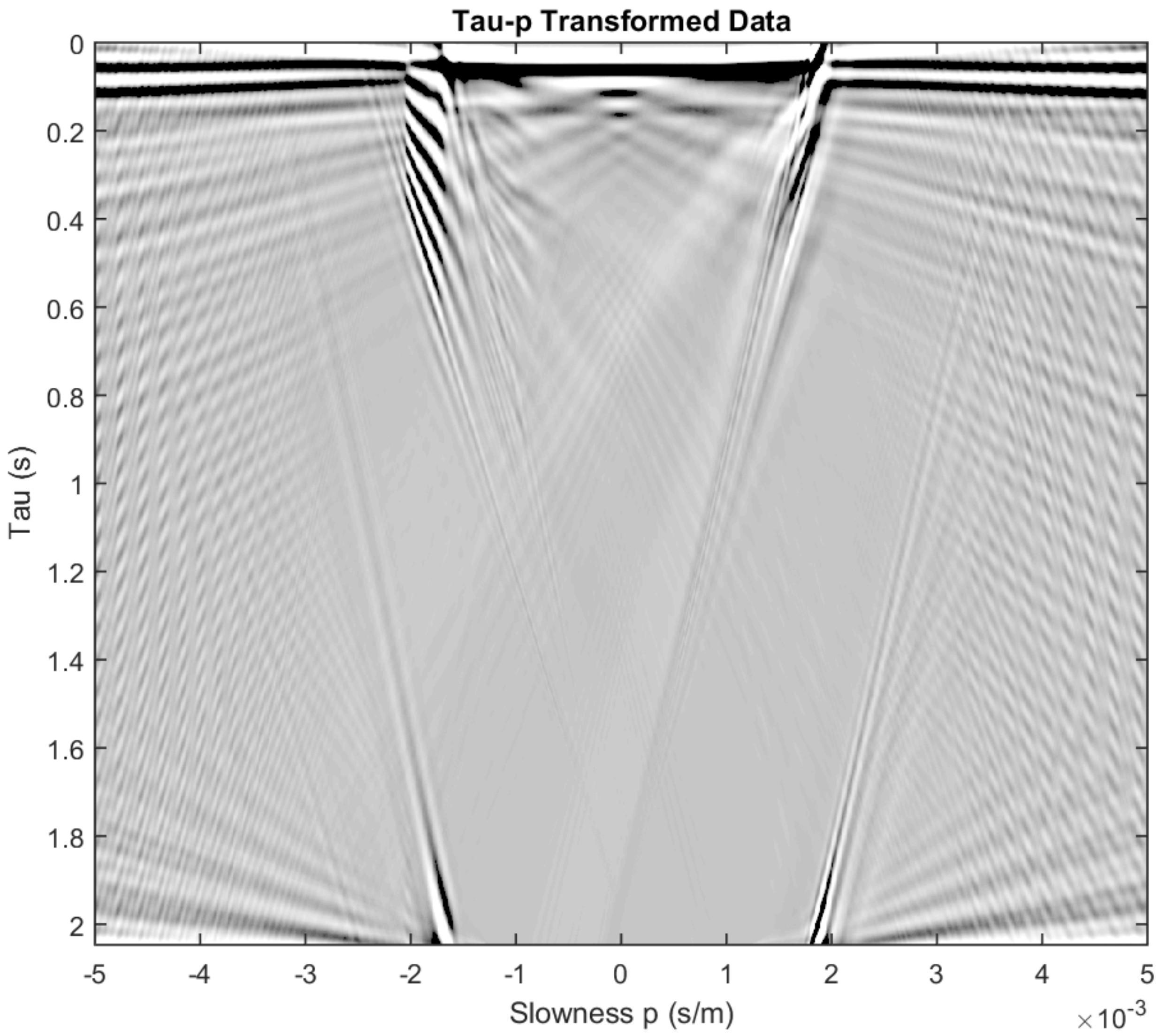
Method 1 – Filtered Dispersion



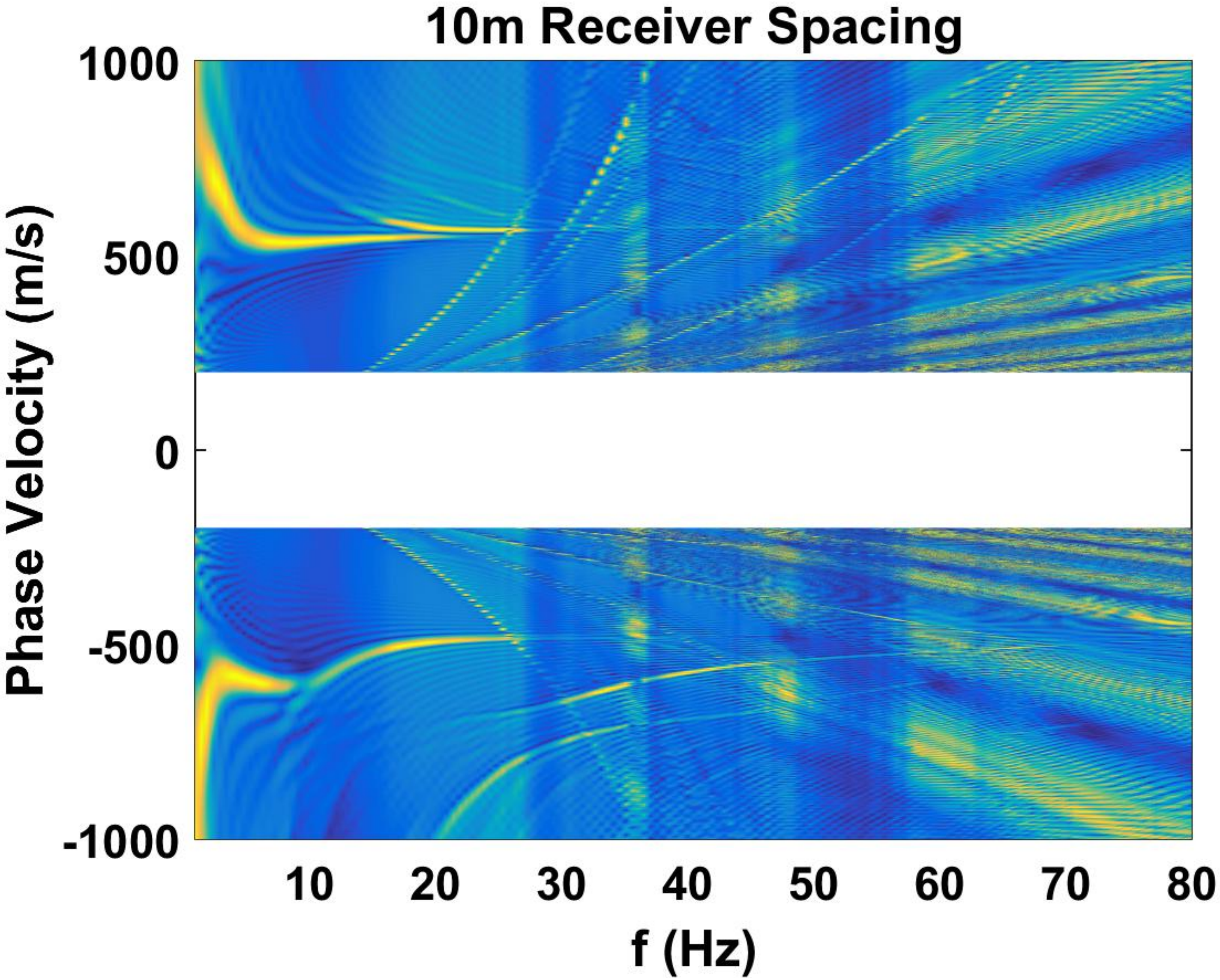
Method 1 – Final Interpolation



Method 1 – Tau-p Data



Method 1 – Final Interpolation Dispersion



Method 2 – Interpolation Followed by Filtering

Interpolation Followed by Filtering

LNMO Correction

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2D Interpolation

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Reverse LNMO Correction

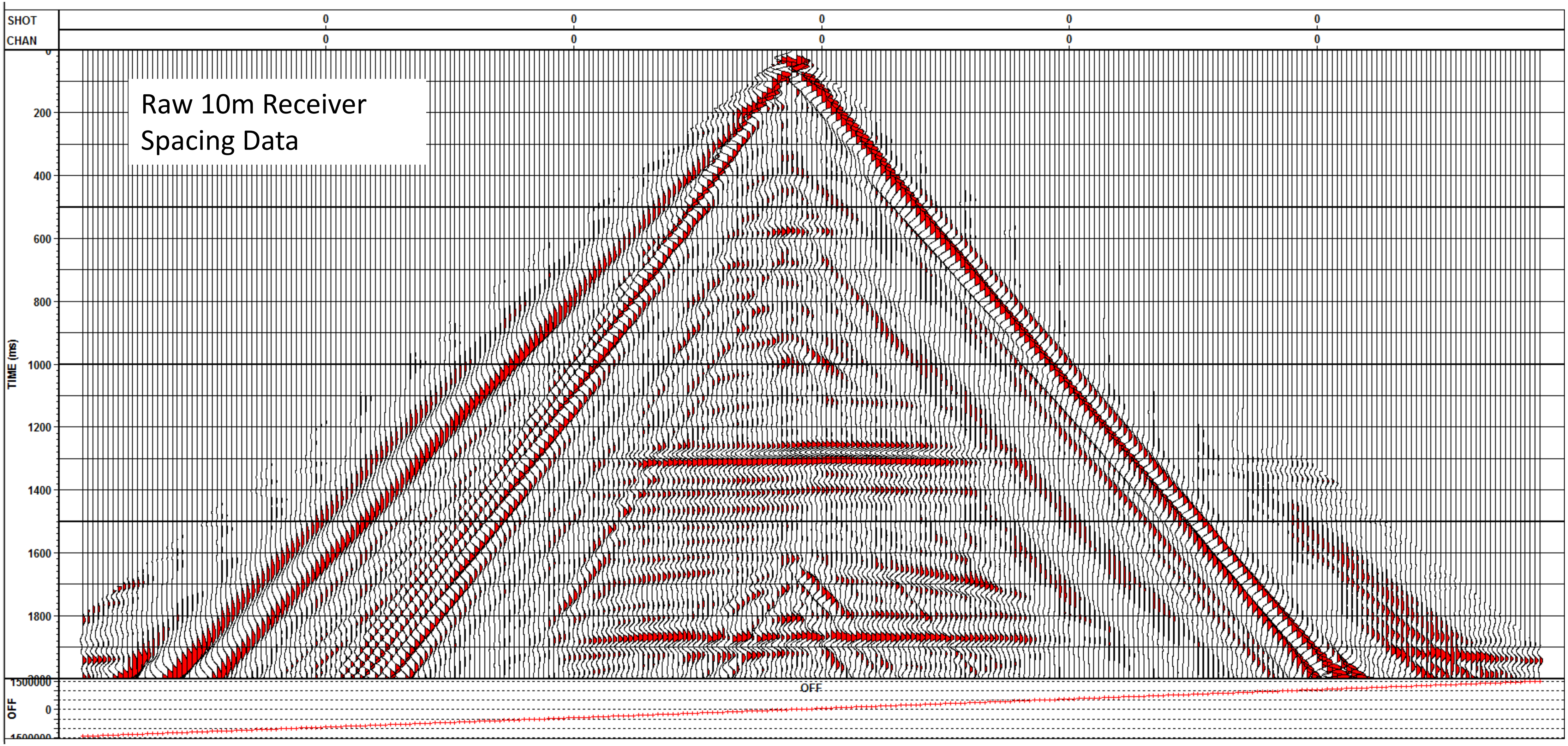
↓

Mute of refractions and direct arrivals

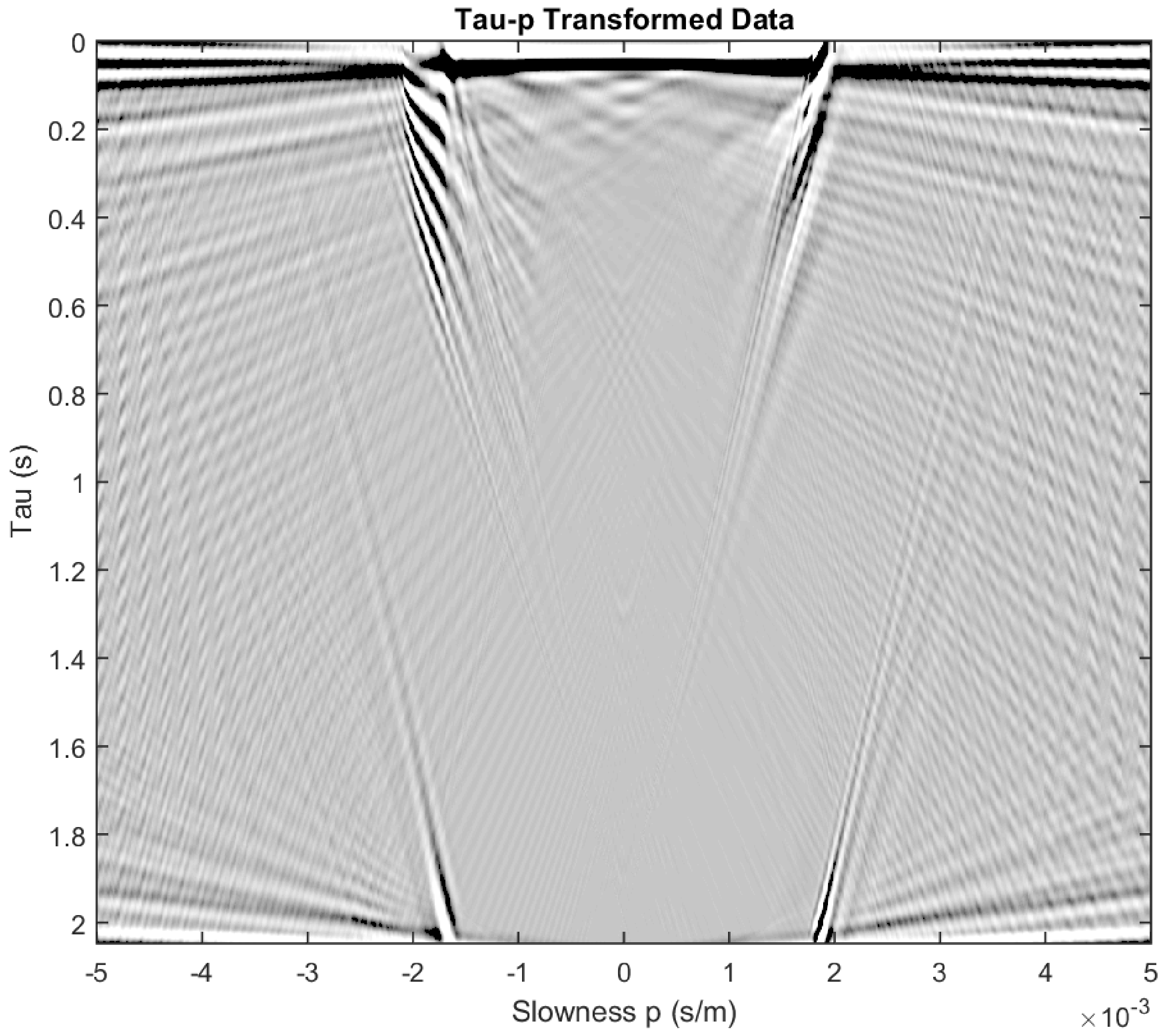
↓

FK Filtering

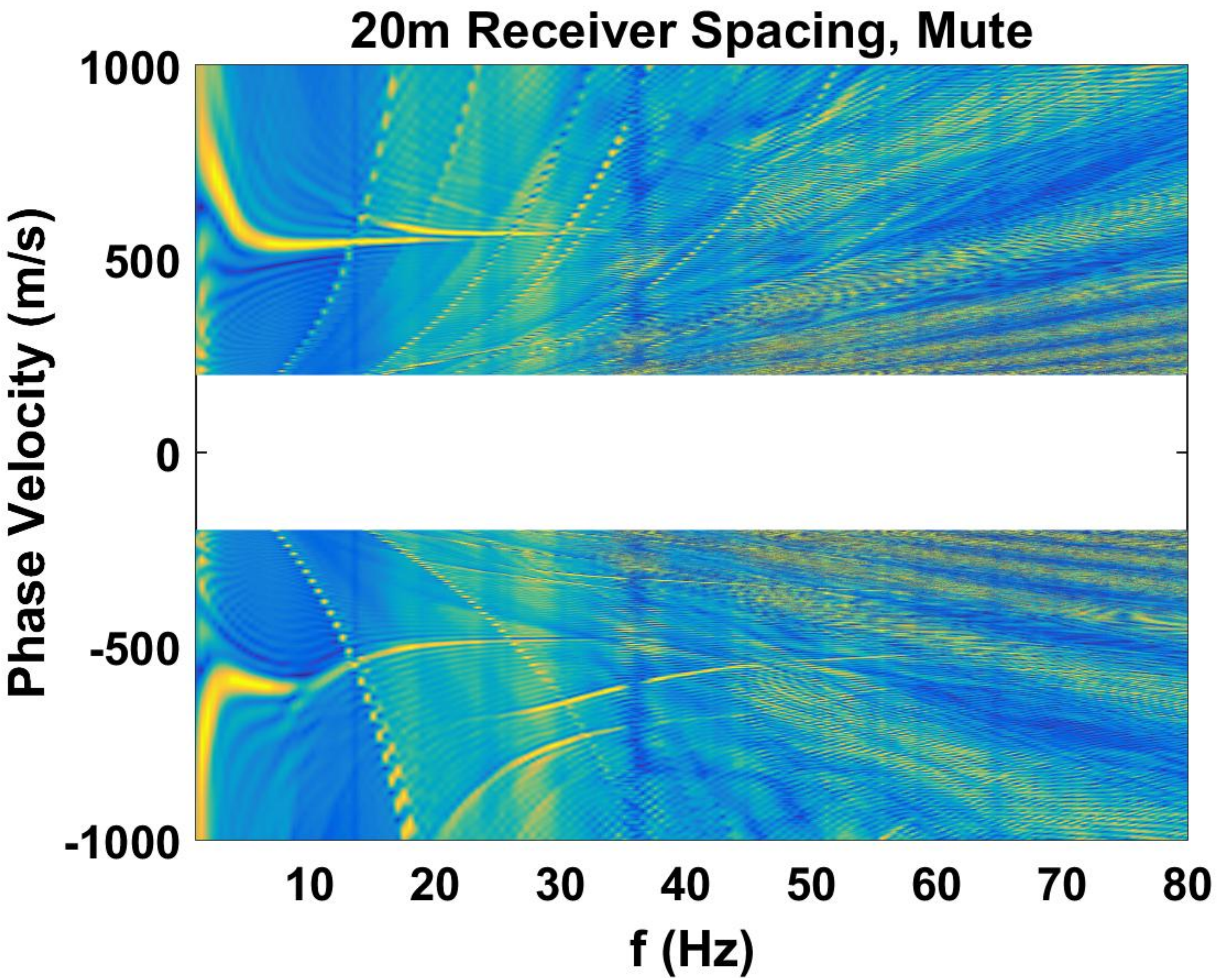
Method 2 – Interpolation



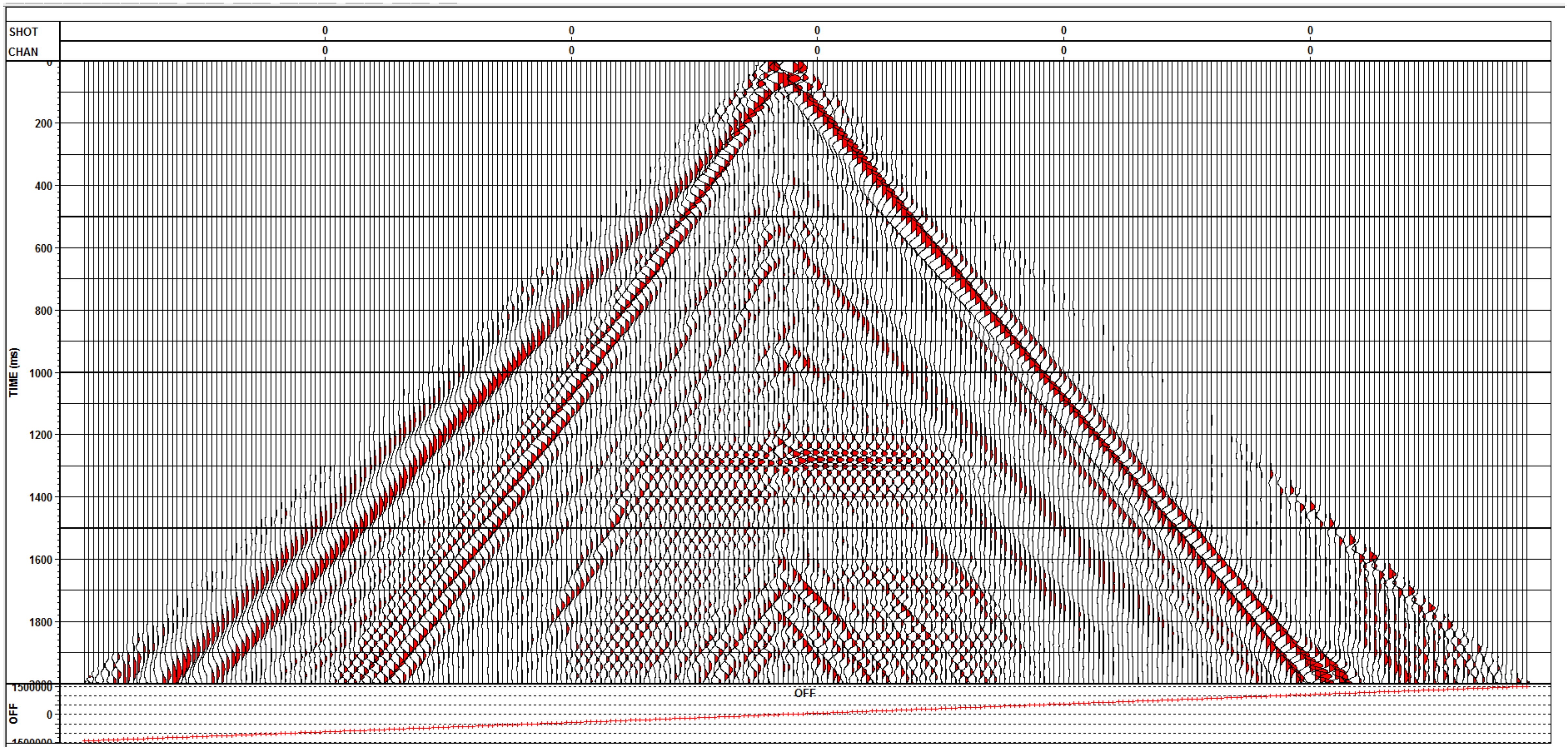
Method 2 – Tau-p Data



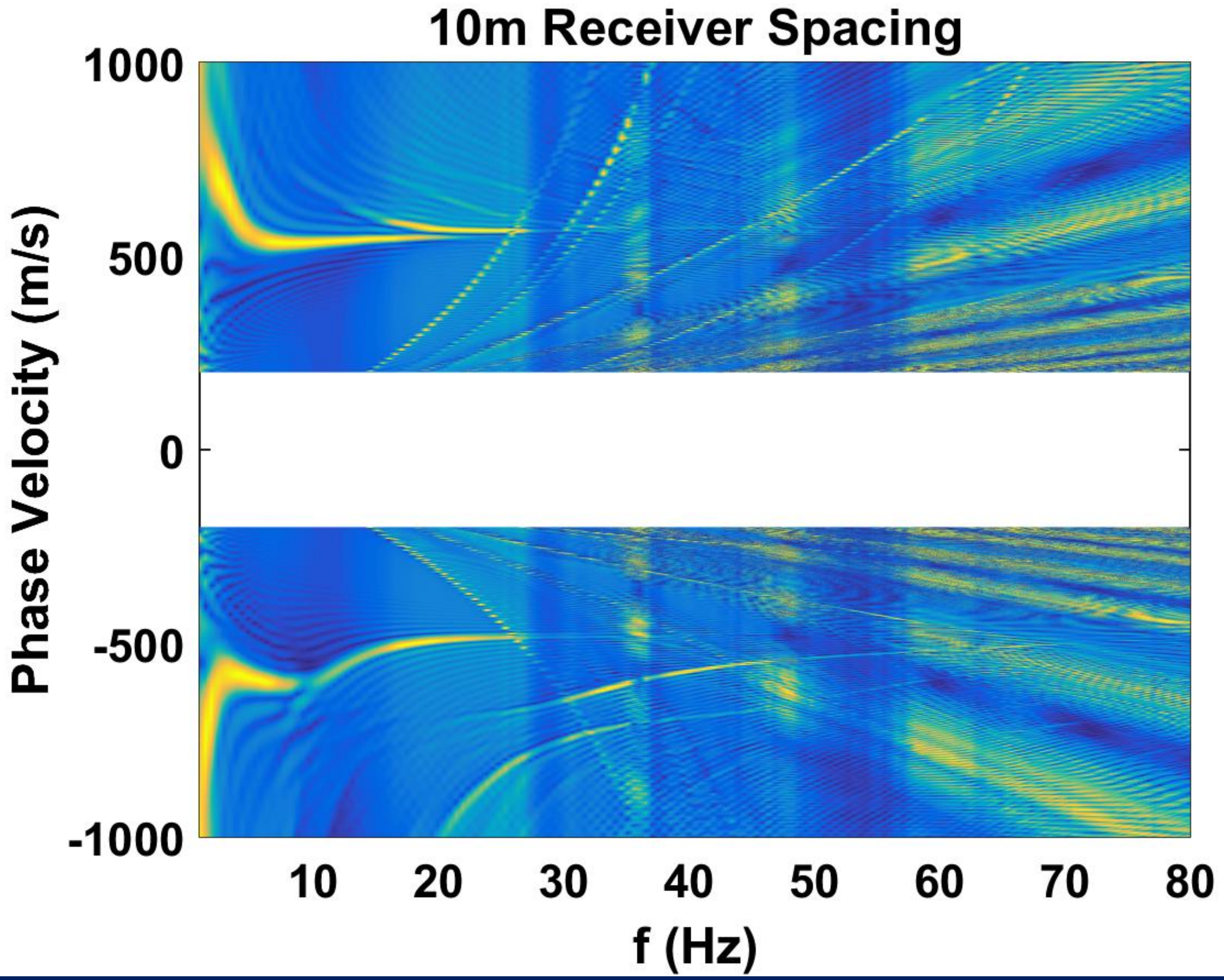
Method 2 – Interpolation Dispersion



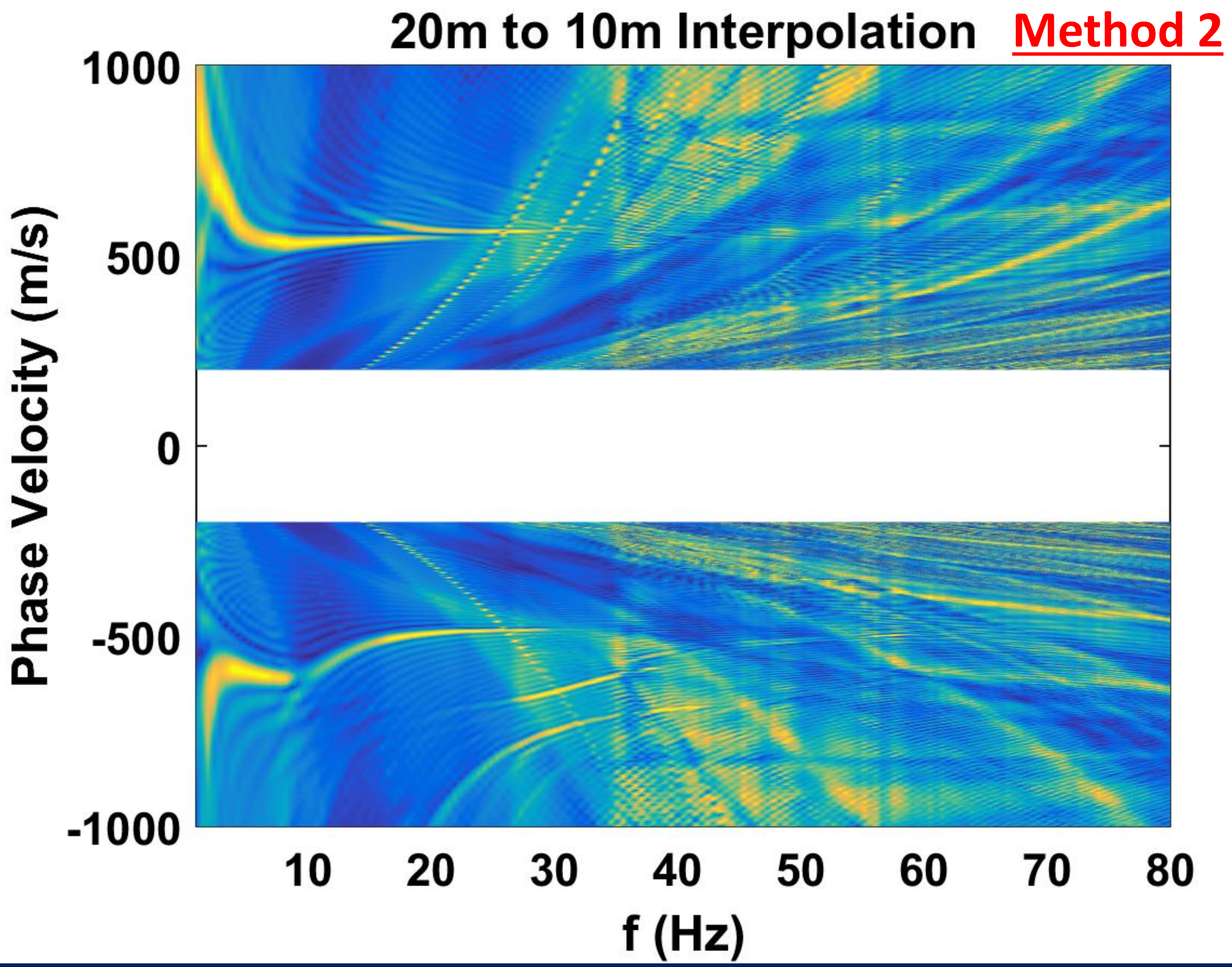
Method 2 – FK Filtered Interpolation



Method 2 – Final Interpolation and Filtered Dispersion



Method Comparison



Conclusions

- Interpolation of sparsely sampled data resulted in significant improvement of dispersion spectra
- Filtering before interpolation results in an obscured dispersion curve at higher frequencies, loss of very low frequencies
  - Removal of aliased data; contains information in those frequencies.
- Following interpolation with FK filtering effective
  - Equivalent to, or better than original closer receiver spacing data

<u>Potential to conduct dispersion studies using data with non-ideal sampling</u>

Existing seismic data libraries

Cheaper acquisition design

Acknowledgements

- CREWES Industrial Sponsors
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- CREWES Staff and Students

Questions

Appendix

2D Trace Interpolation

- Requires NMO corrections (sub-horizontal events) and de-noising before interpolation
  - LNMO correction applied using average ground roll velocity**
- Traces are added by deconvolution of the original data - operator built from original traces in the FK domain.
  - Iterated 10 times
- LNMO correction reversed using **