Direct measurement of frequency-dependent phase velocities from Snowflake data

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CREWES sponsor meeting

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Carbon Management Canada

Outline

- Motivation
- Background
- Method
- Discussion
  - Semi-automatic picking procedure
  - Automatic picking procedure
- Summary

Motivation

- In a dispersive medium, seismic waves of varying frequencies travel with different velocities; leading to frequency-dependent attenuation.

- Understanding the dispersive properties in the near-surface by estimating the frequency-dependent phase velocity helps in determining the quality factor(Q).

Background

CMC Newell County Facility

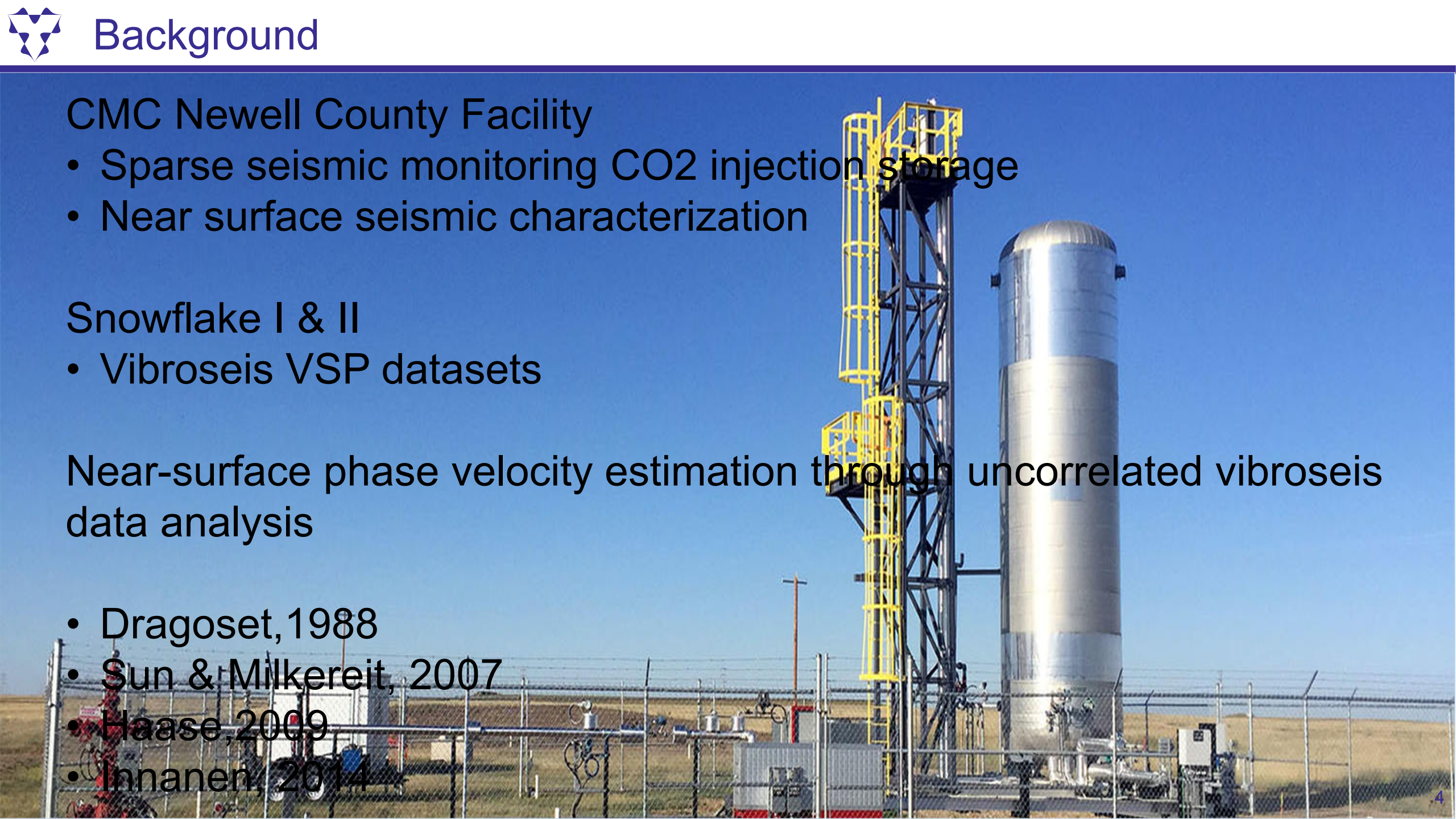
- Sparse seismic monitoring CO2 injection storage
- Near surface seismic characterization

Snowflake I & II

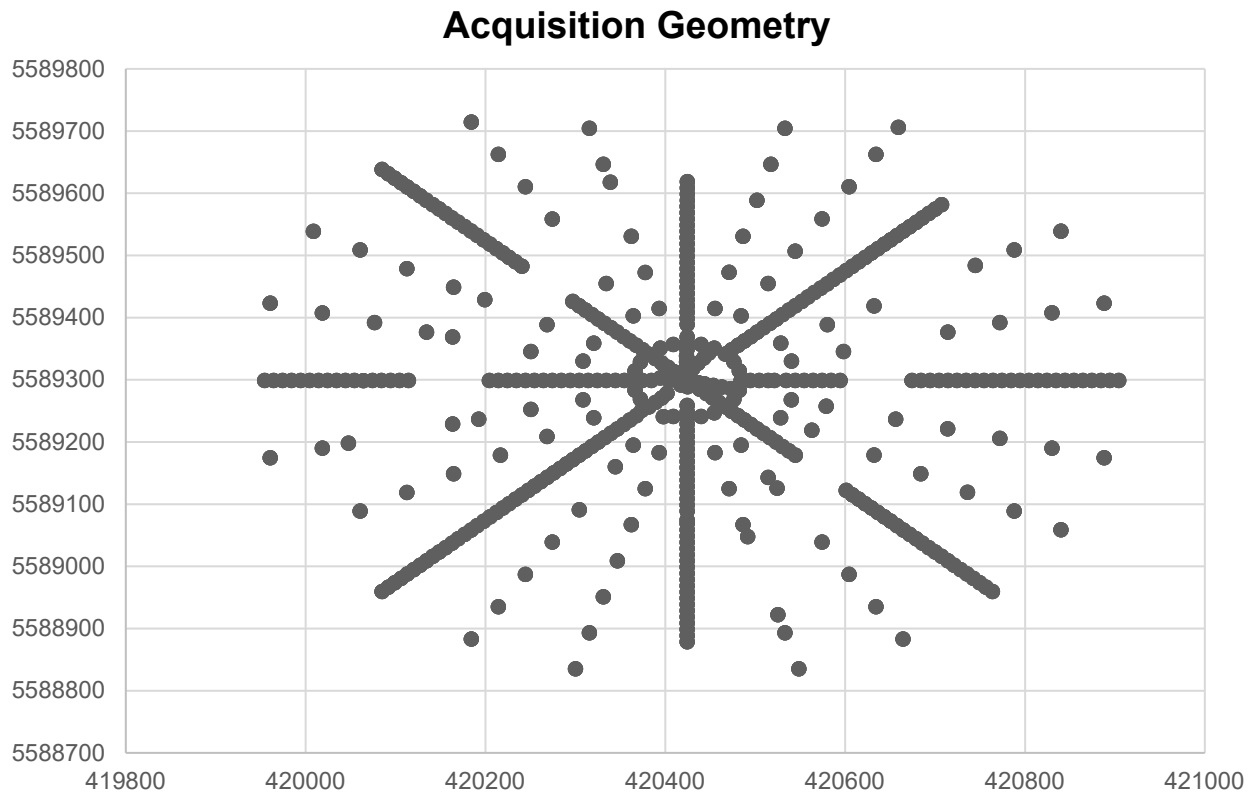
- Vibroseis VSP datasets

Near-surface phase velocity estimation through uncorrelated vibroseis data analysis

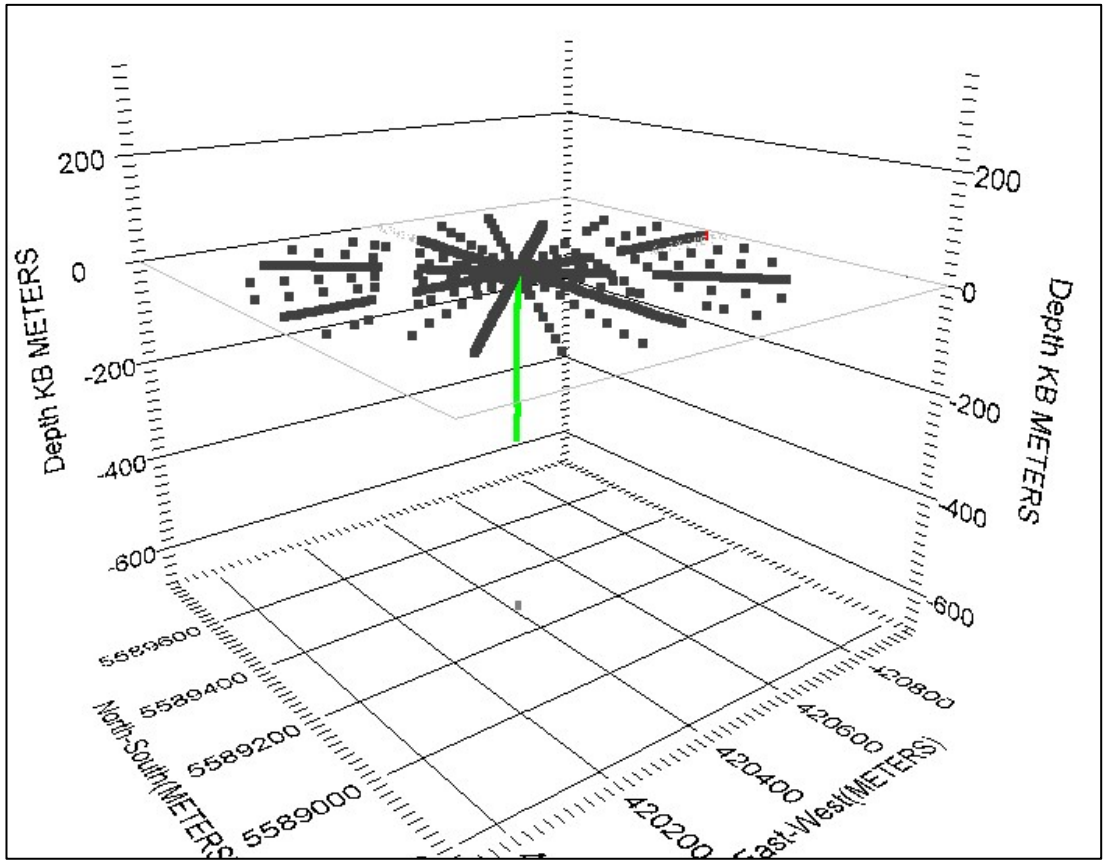
- Dragoset,1988
- Sun & Milkereit, 2007
- Haase,2009
- Innanen, 2014



Acquisition Geometry



Planar View



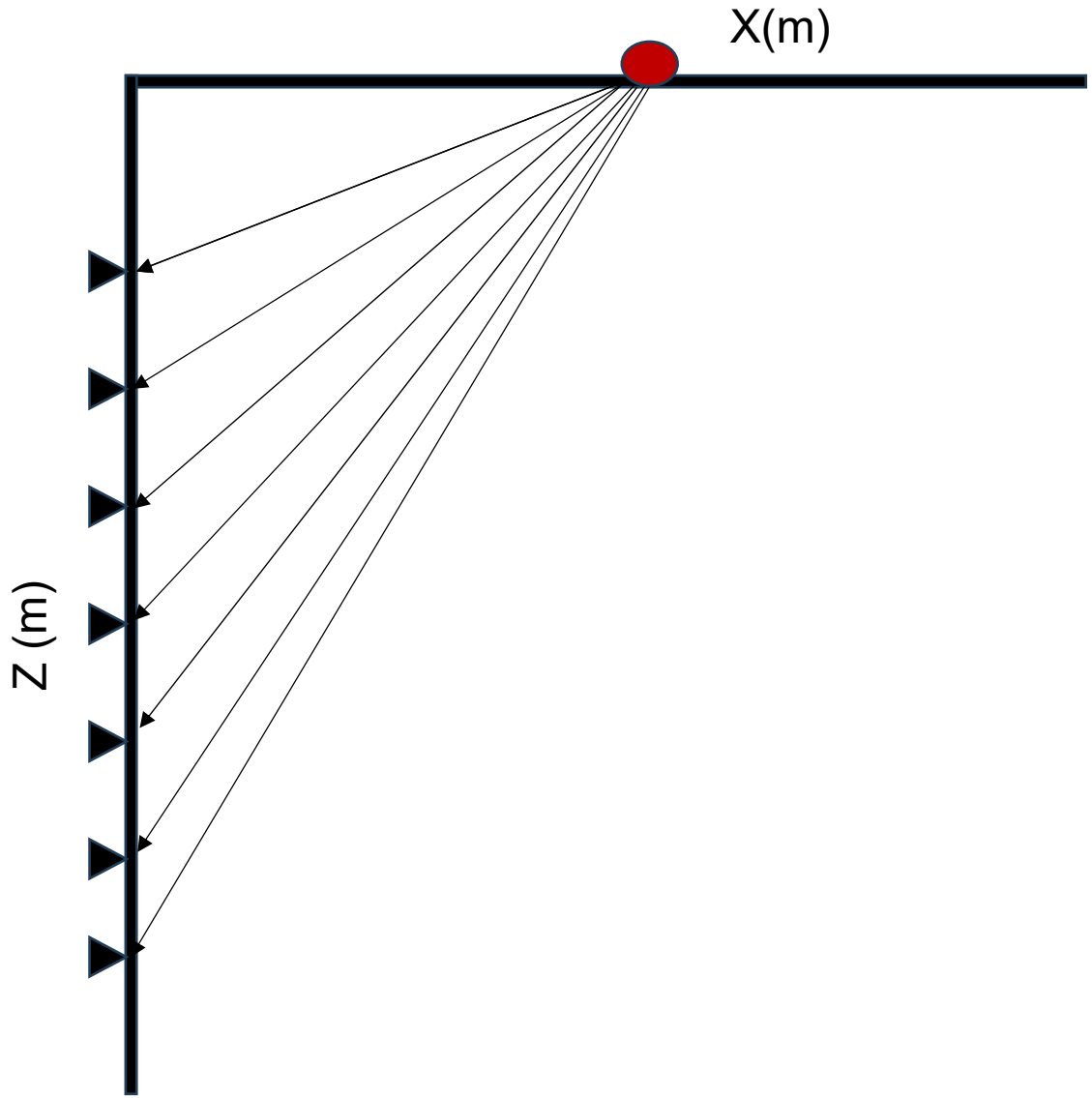
Side view

Phase Velocity

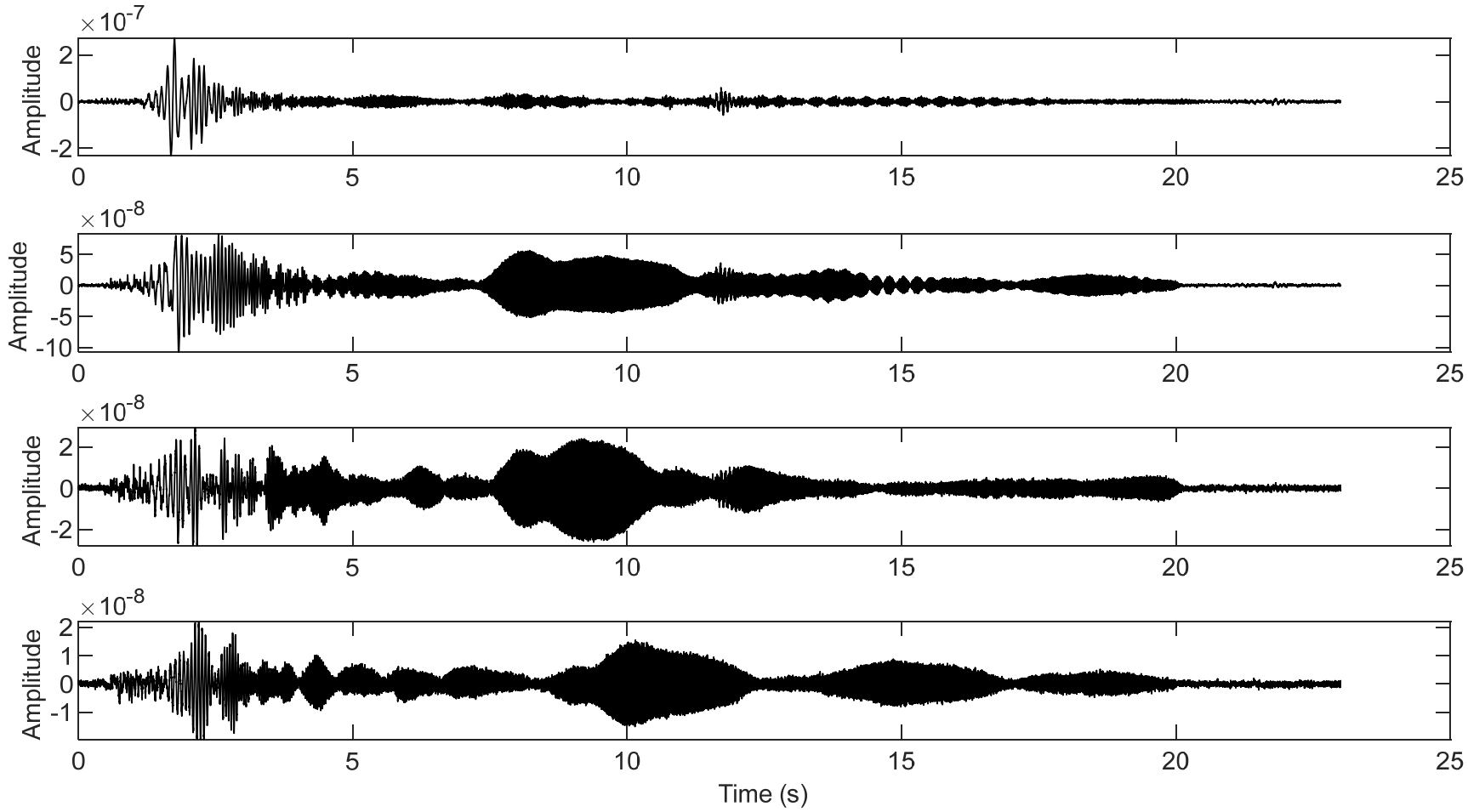
$$V_p(f) = \frac{L}{\Delta T(f)}$$

$$L = \sqrt{x^2 + z^2}$$

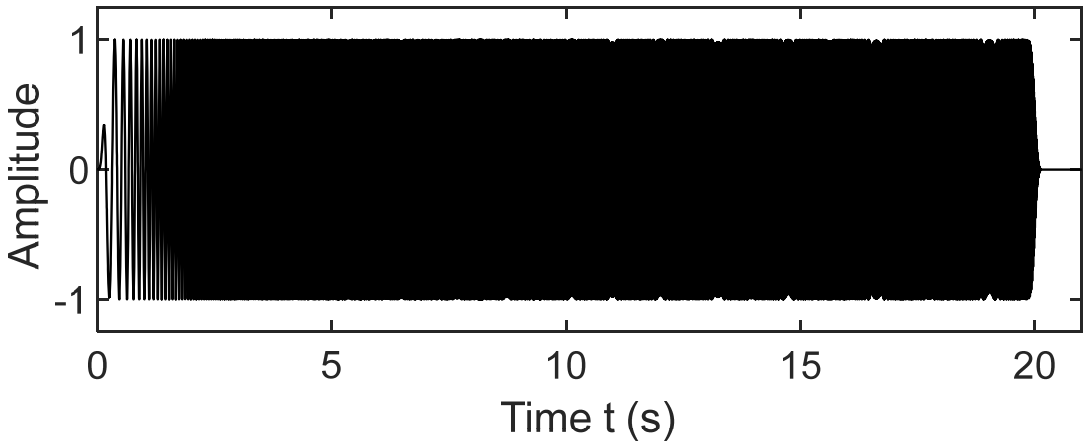
$$\Delta T(f) = T_M(f) - T_s(f)$$

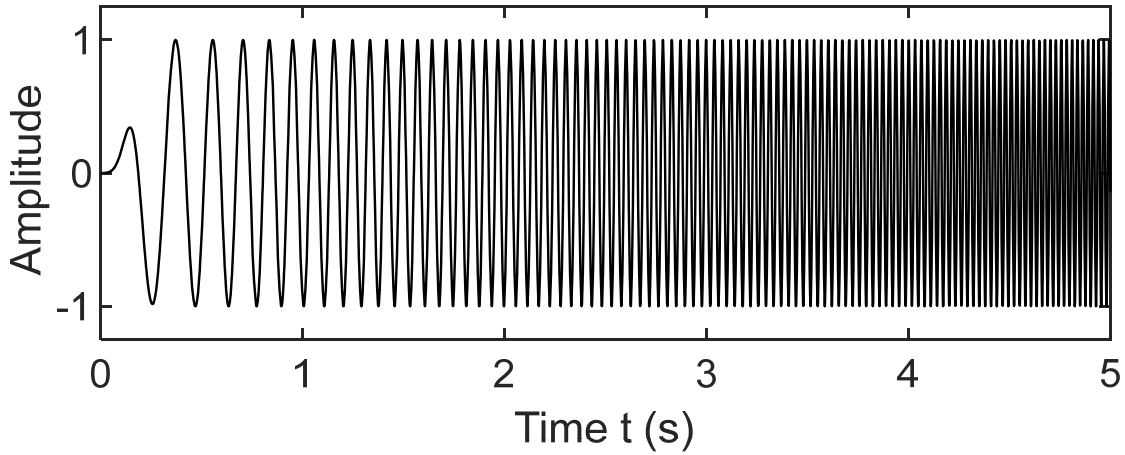


Extracting uncorrelated seismic traces from a shot record



Estimating the source signal

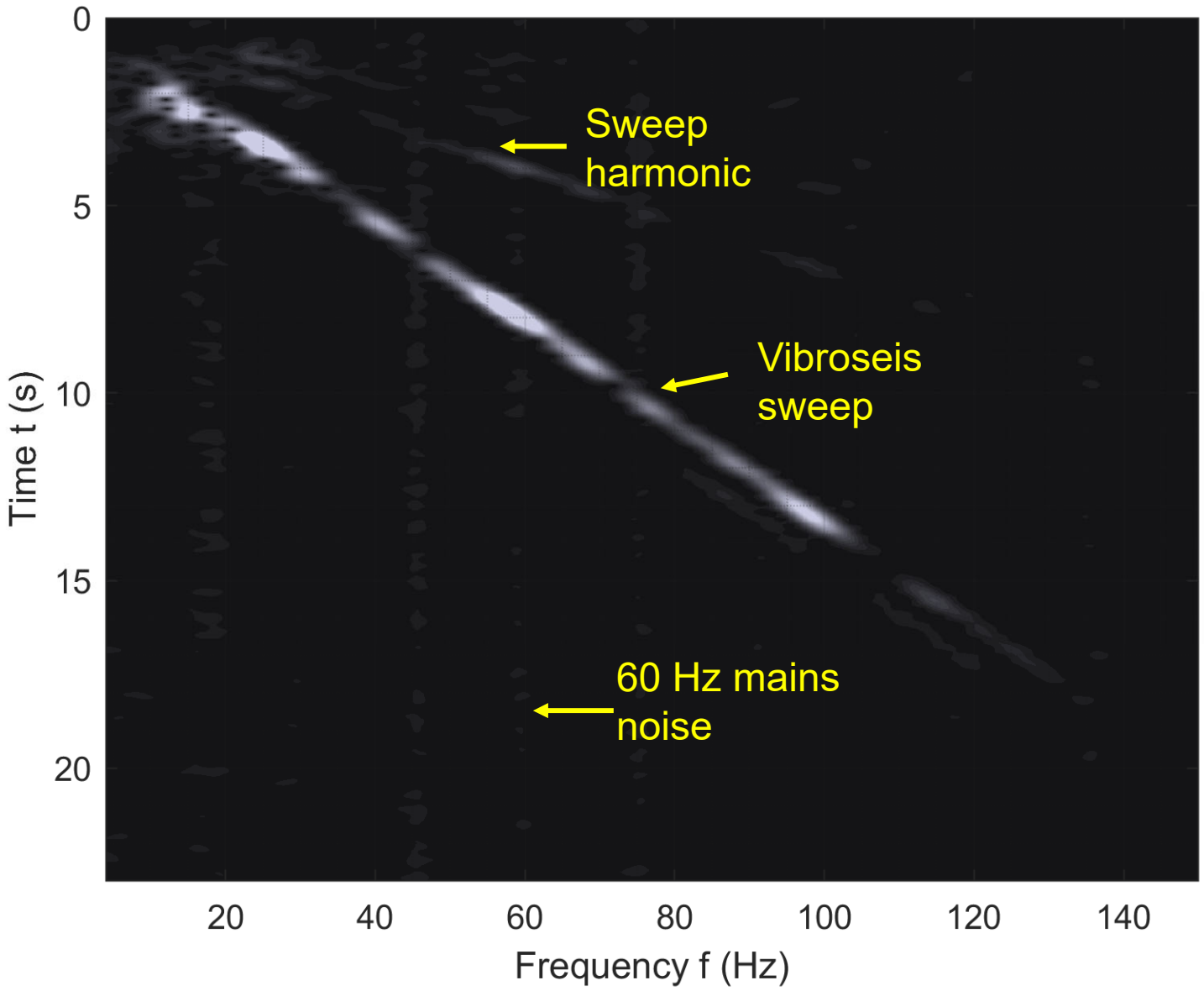




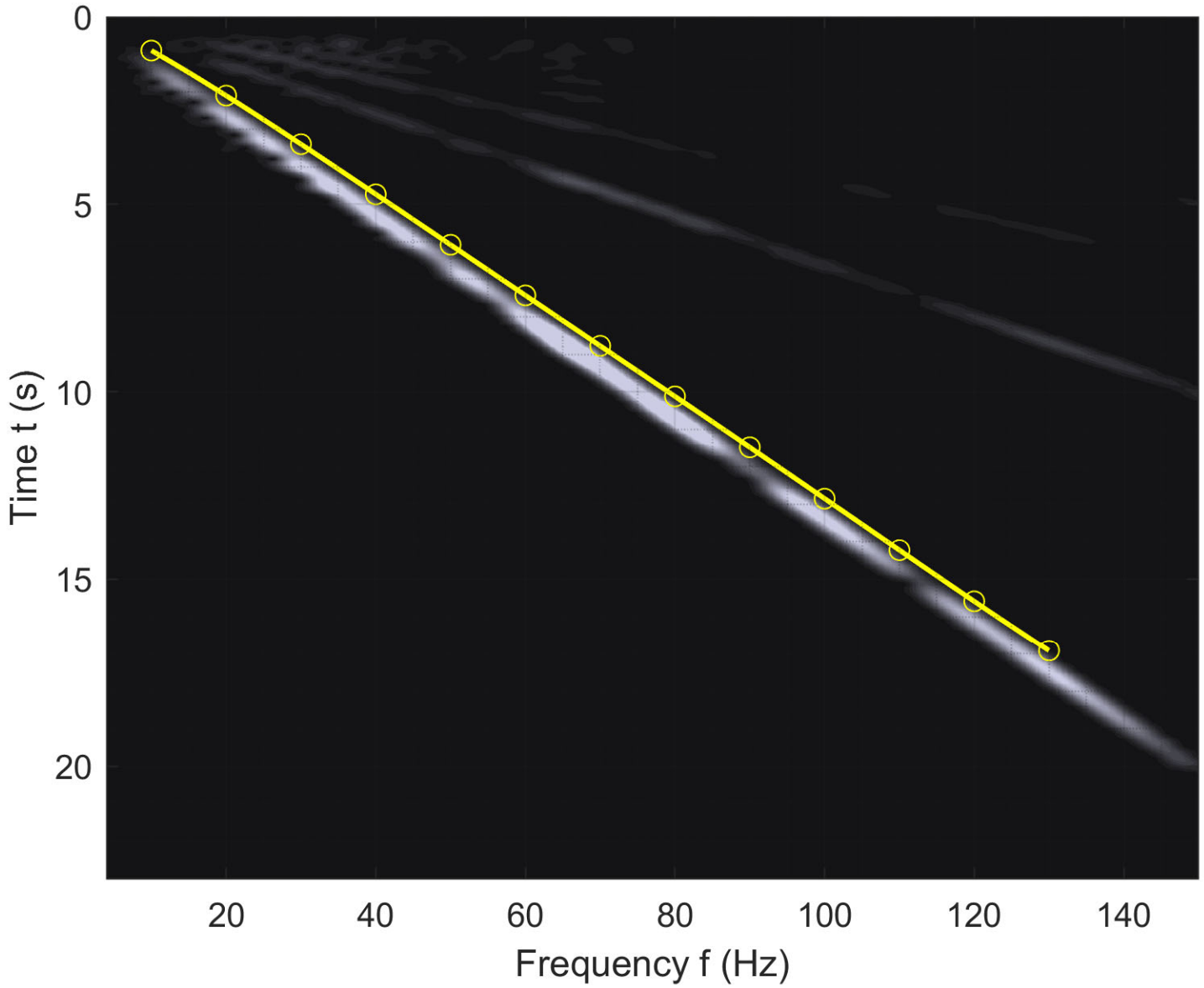
$$fmin = 2Hz$$
$$fmax = 150\text{Hz}$$
$$T = 20\text{s}$$

$$\text{S}(t) = \text{Im}[\text{a(t)e}^{i\emptyset(t)}] \;;\; \emptyset(\text{t}) = 2\pi f(\text{t})\text{t} \;;\; f(t) = fmin + \frac{(fmax - fmin)t}{T}$$

Gabor spectrum of a seismic trace

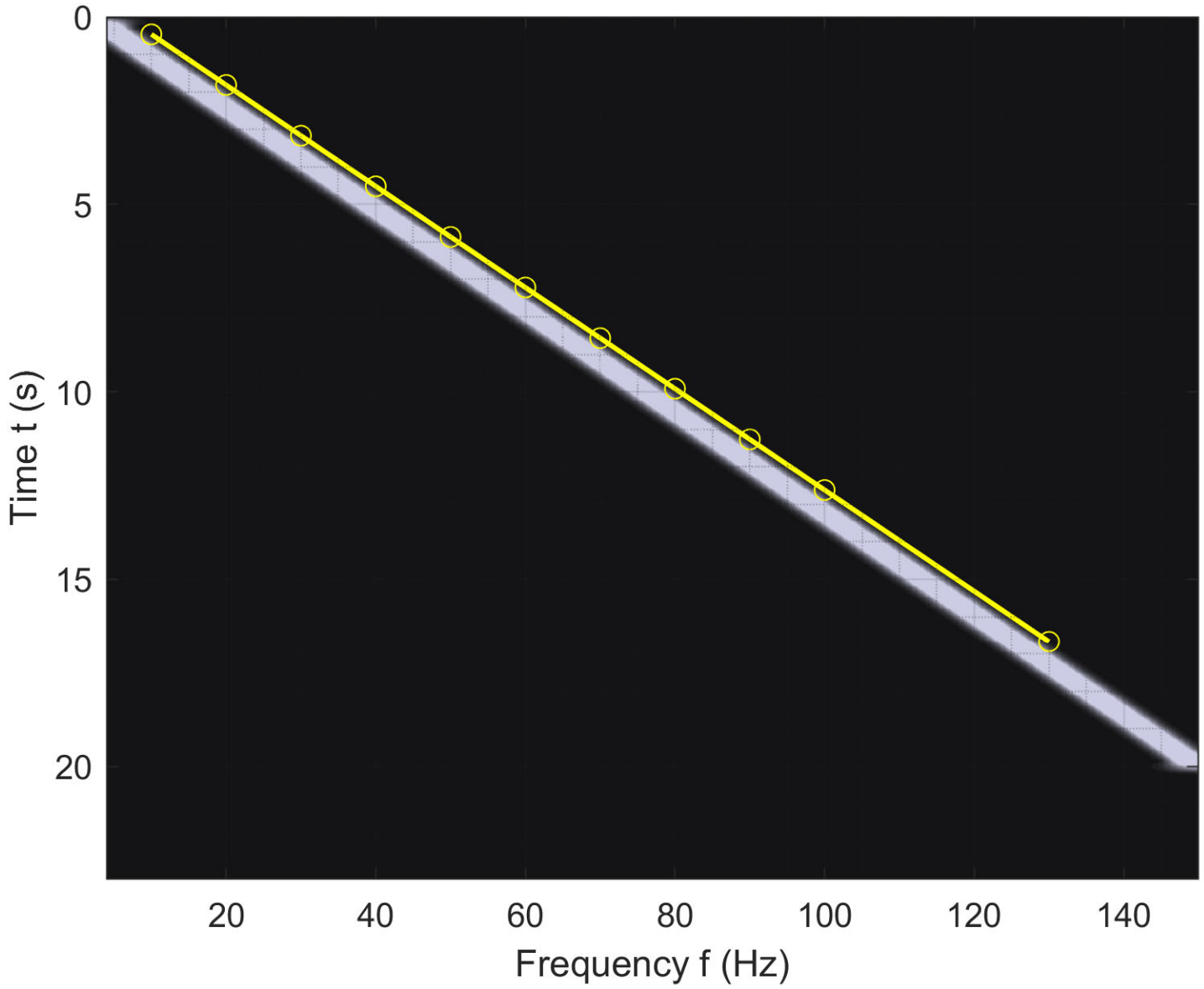


Arrival time picks on the seismic trace Gabor spectrum

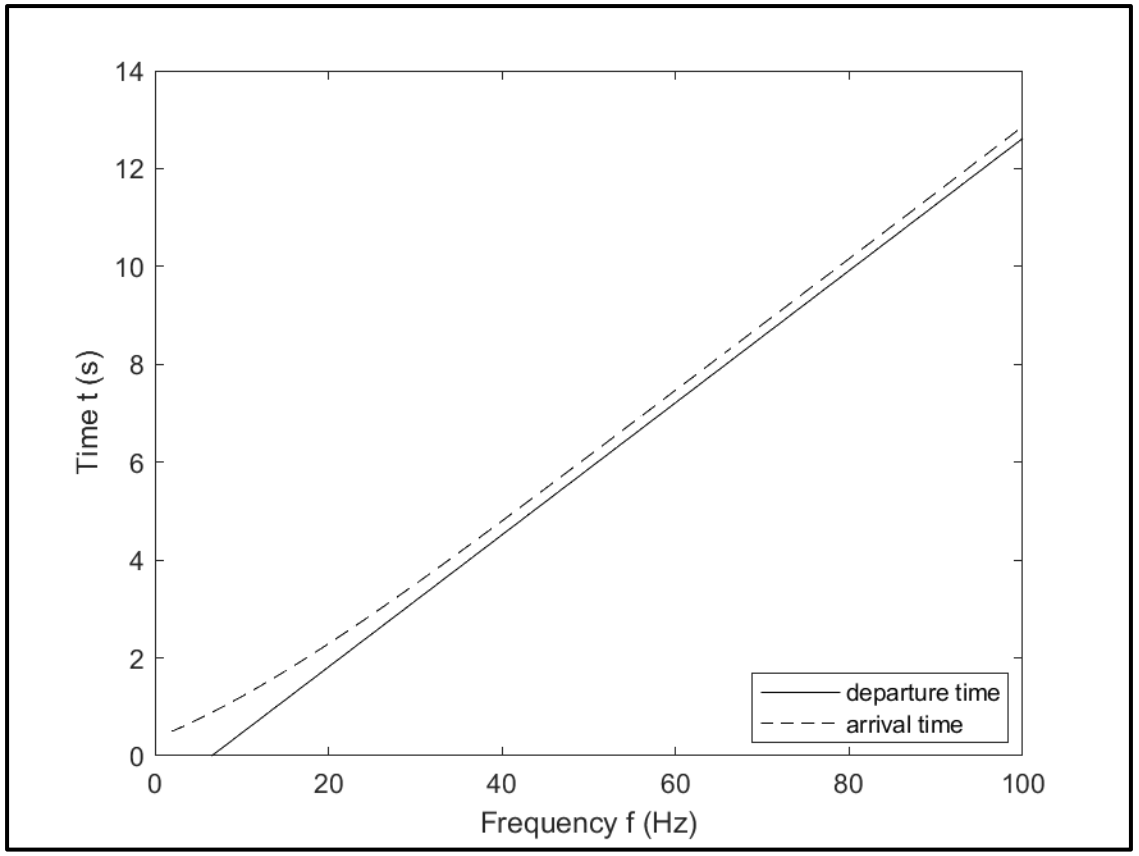


Depth =140m

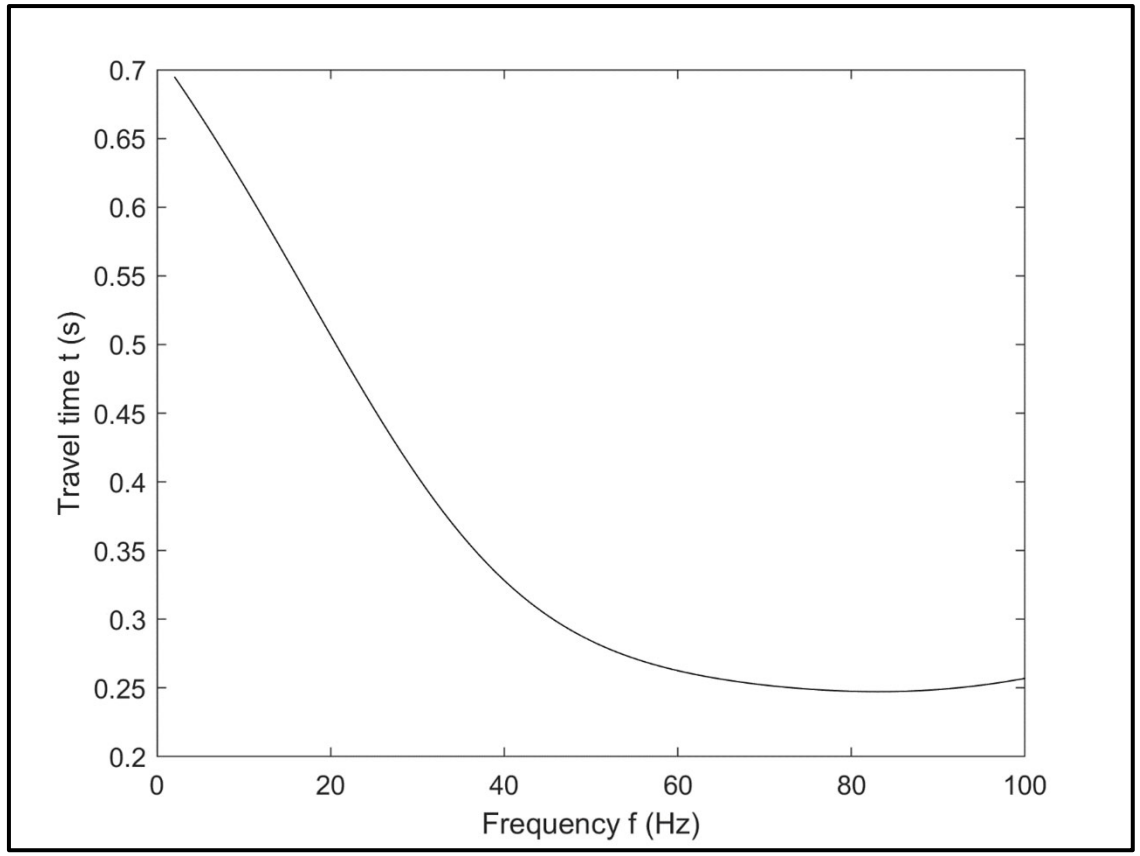
Departure time picks on the linear sweep Gabor spectrum



Travel time of the frequency

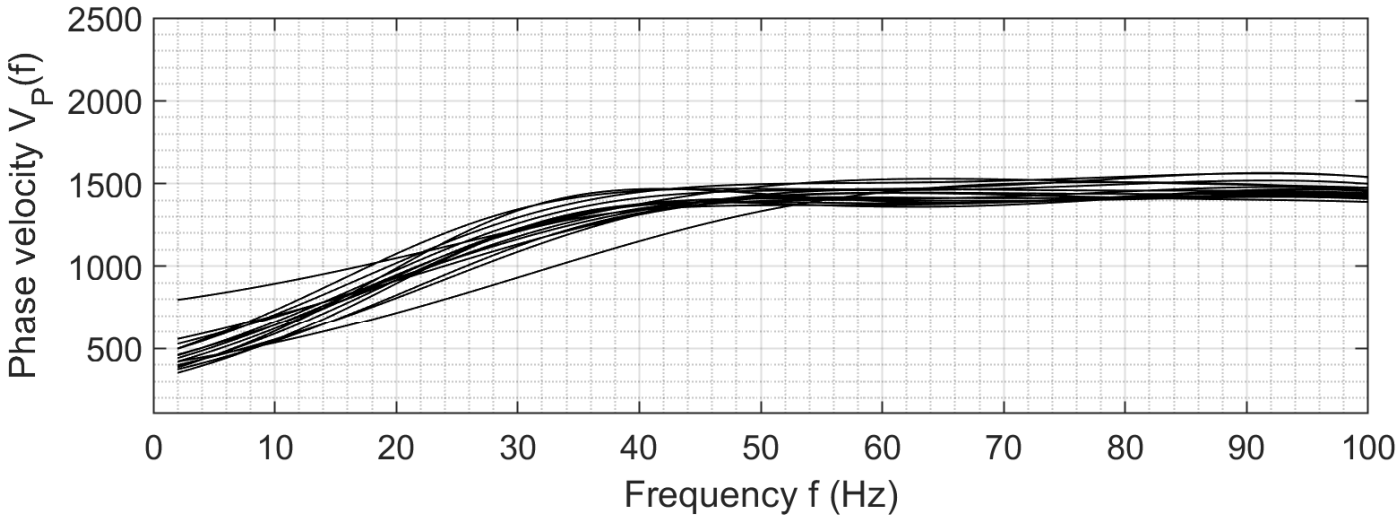


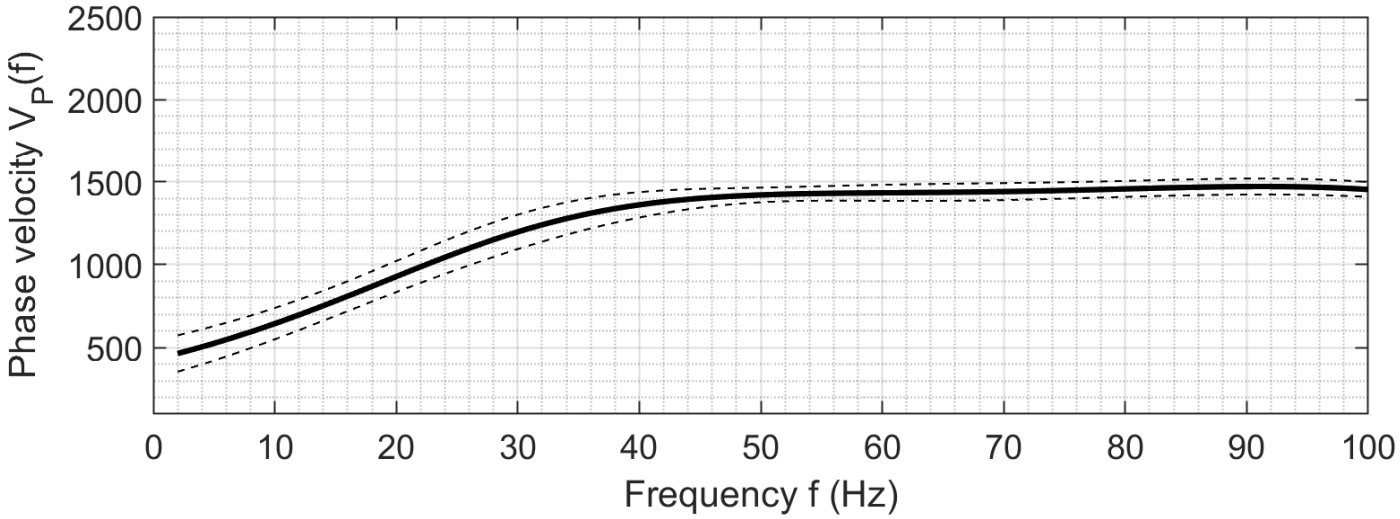
Overlay of arrival and departure time picks



Travel time of the frequencies

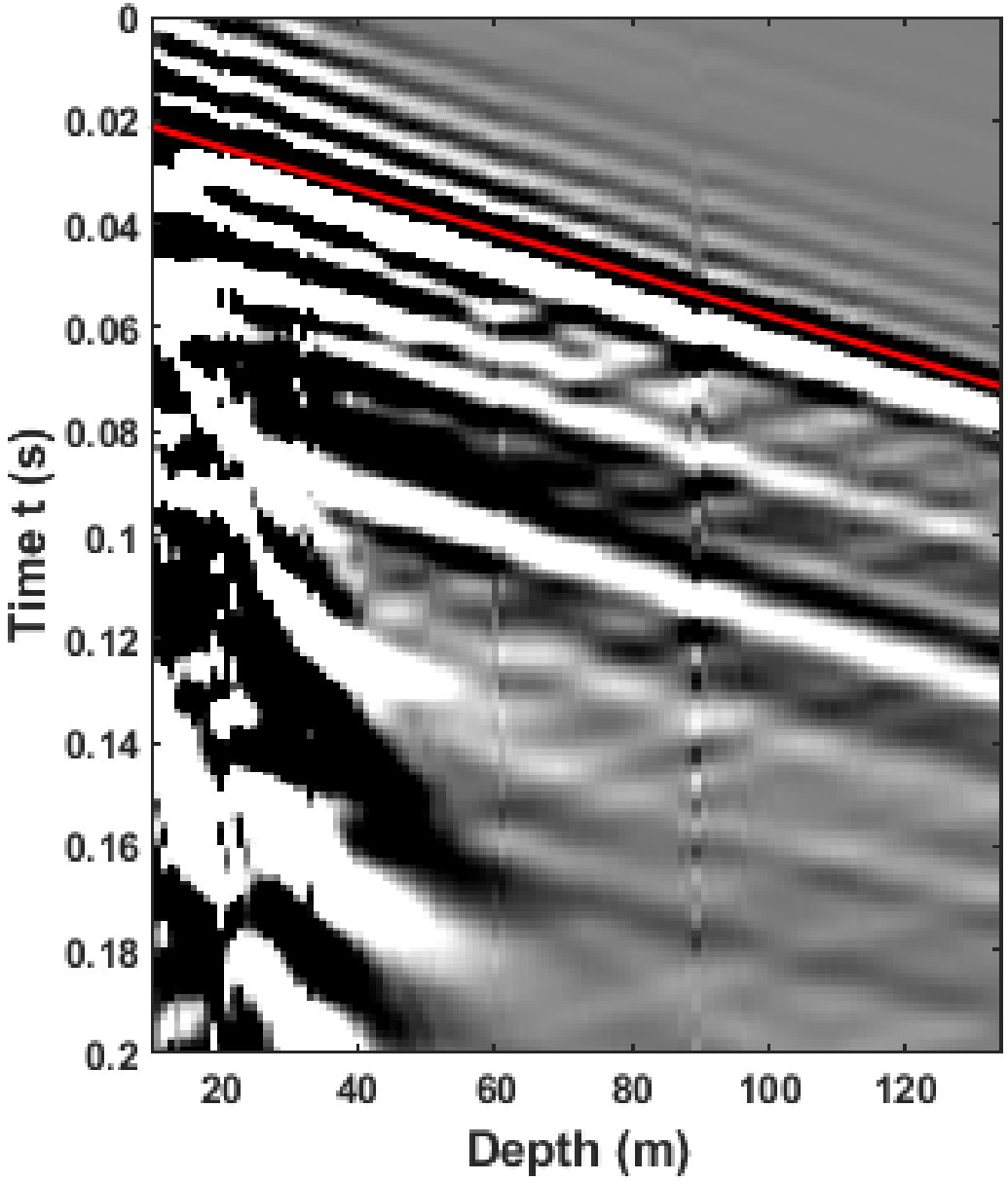
Estimating the uncalibrated(raw) phase velocity





Depth = 1-150m

Group velocity estimated from the P-wave arrival

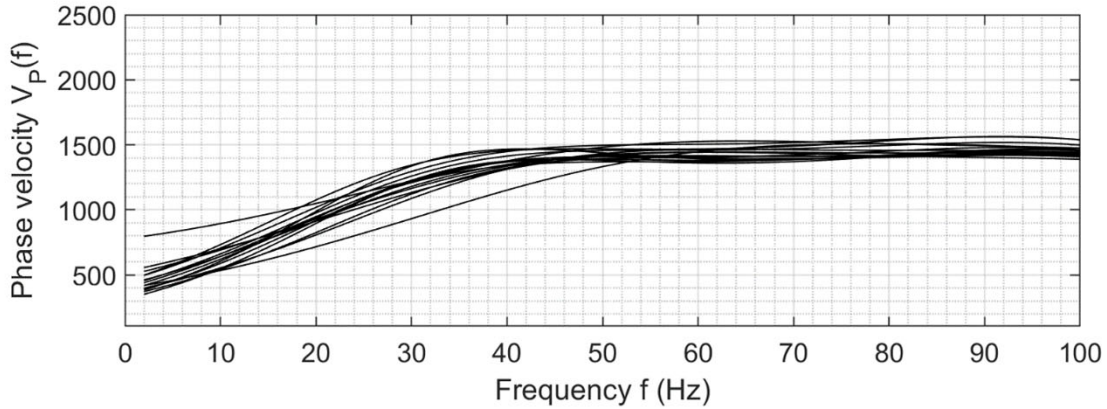


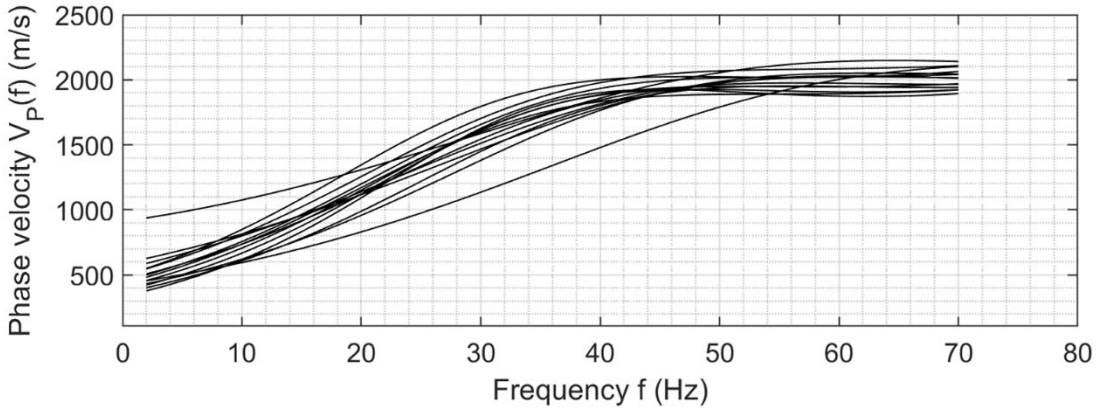
Estimation of calibrated phase velocity

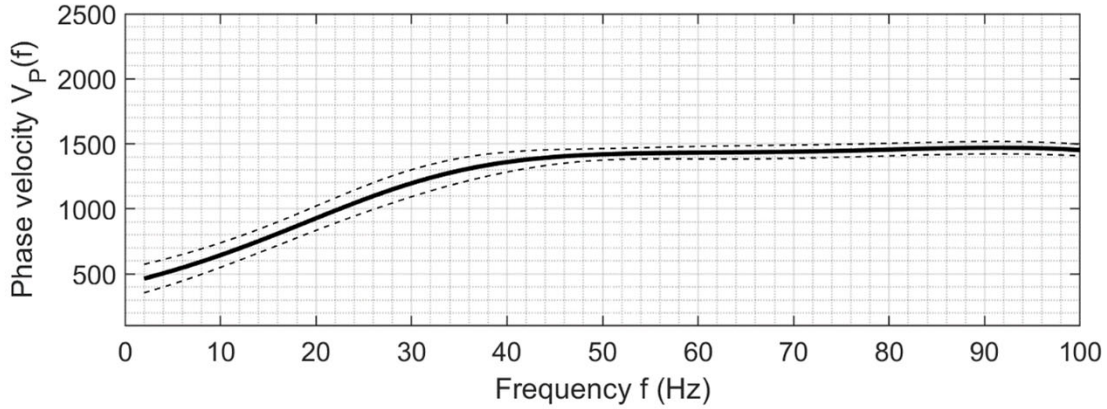
$$V_{p(f)} = \frac{L}{T_{M(f)} - T_{s(f)} - T_{cal}}$$

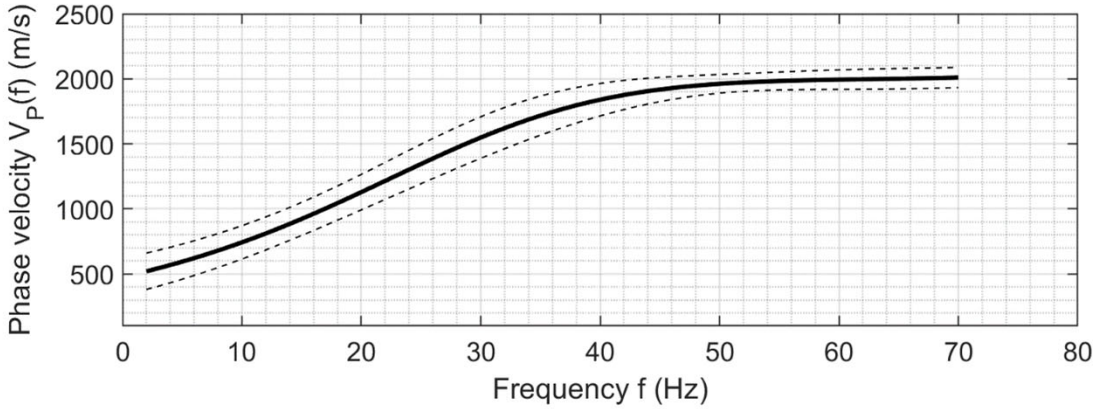
Uncalibrated phase velocity

Calibrated Phase Velocity

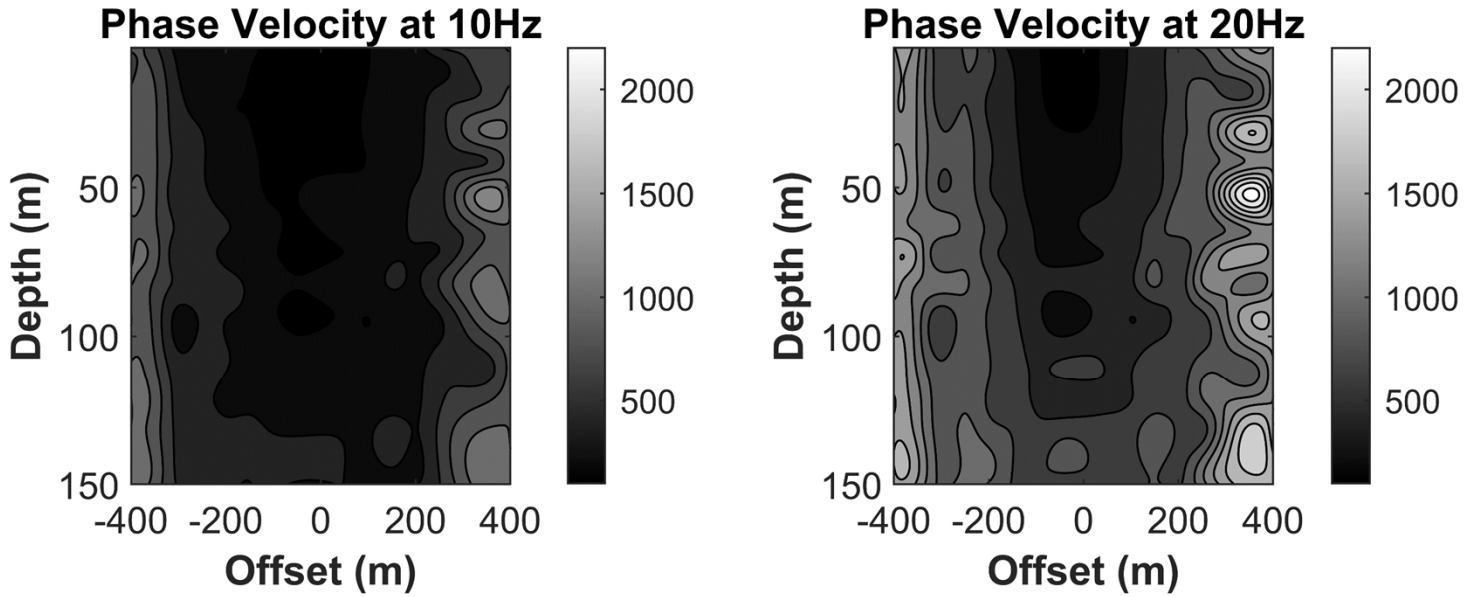


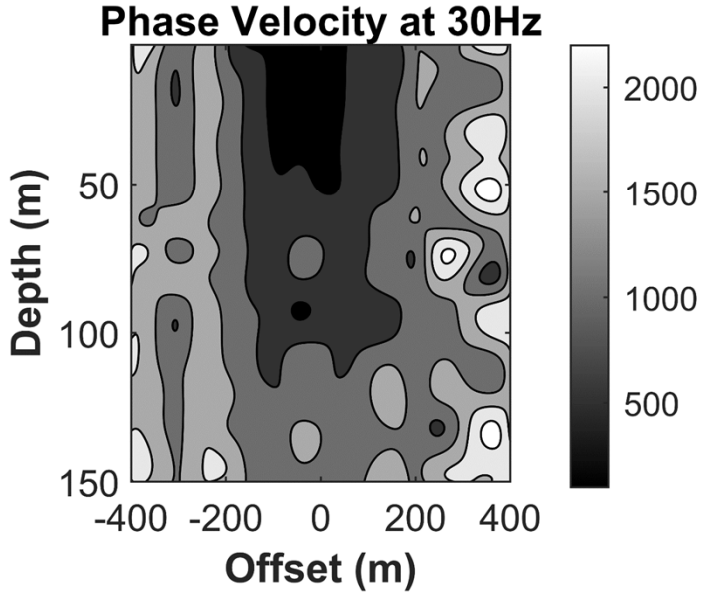


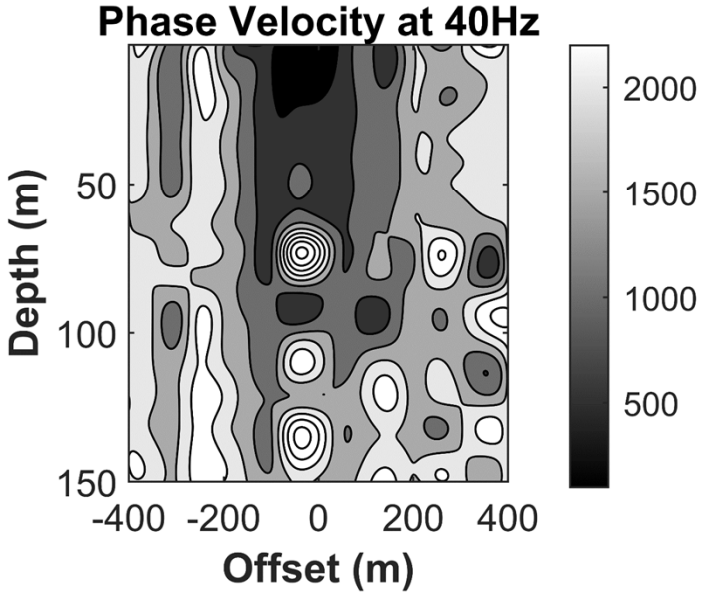


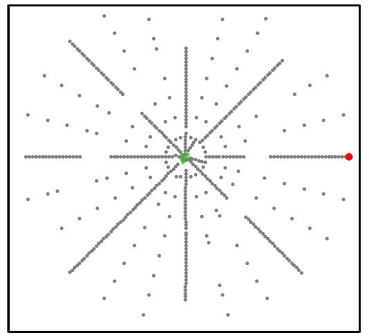


Phase velocity maps









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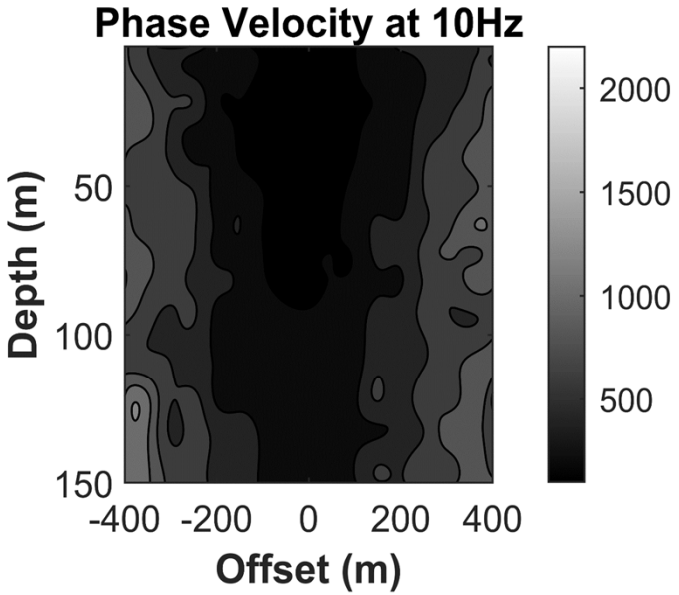
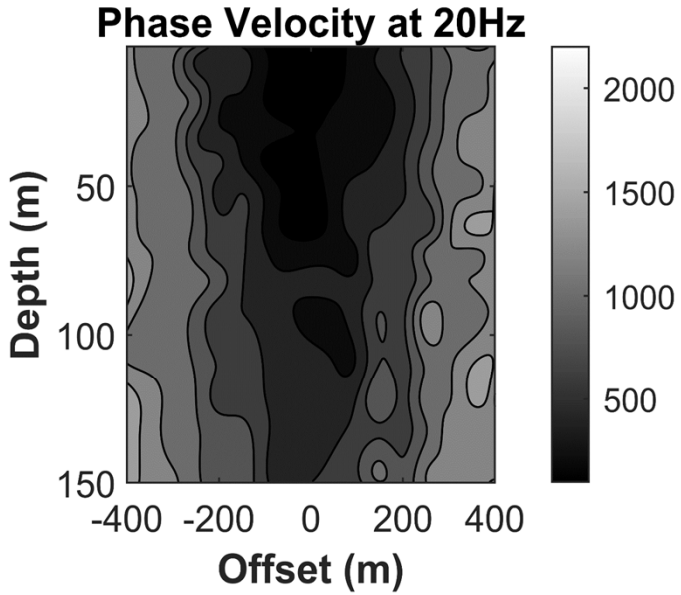
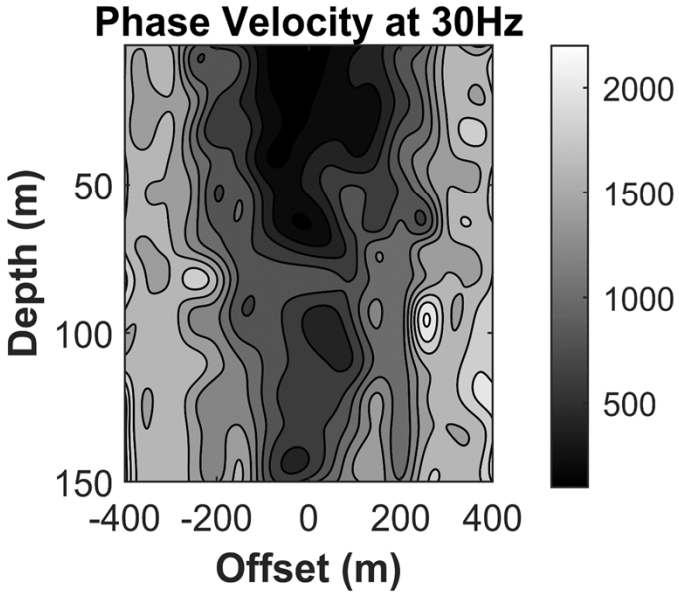
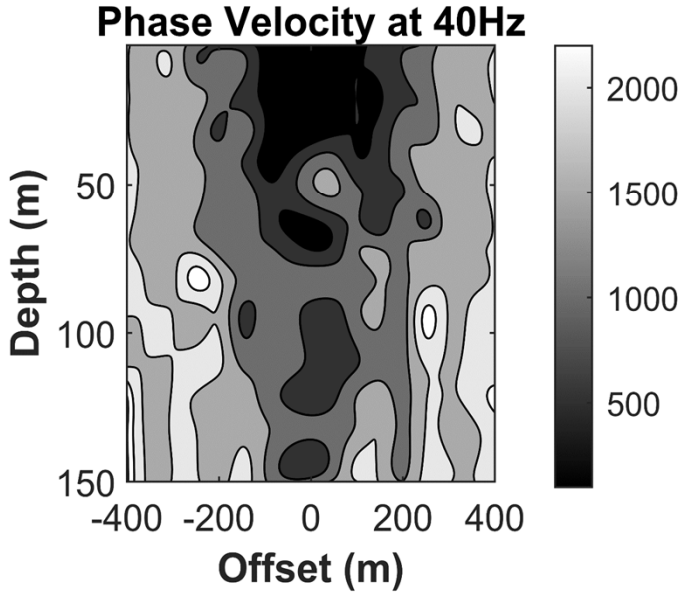
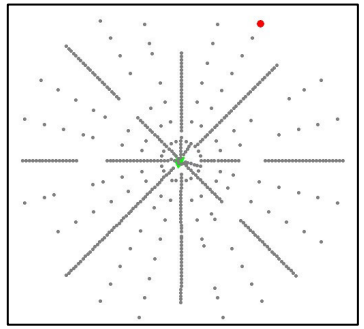


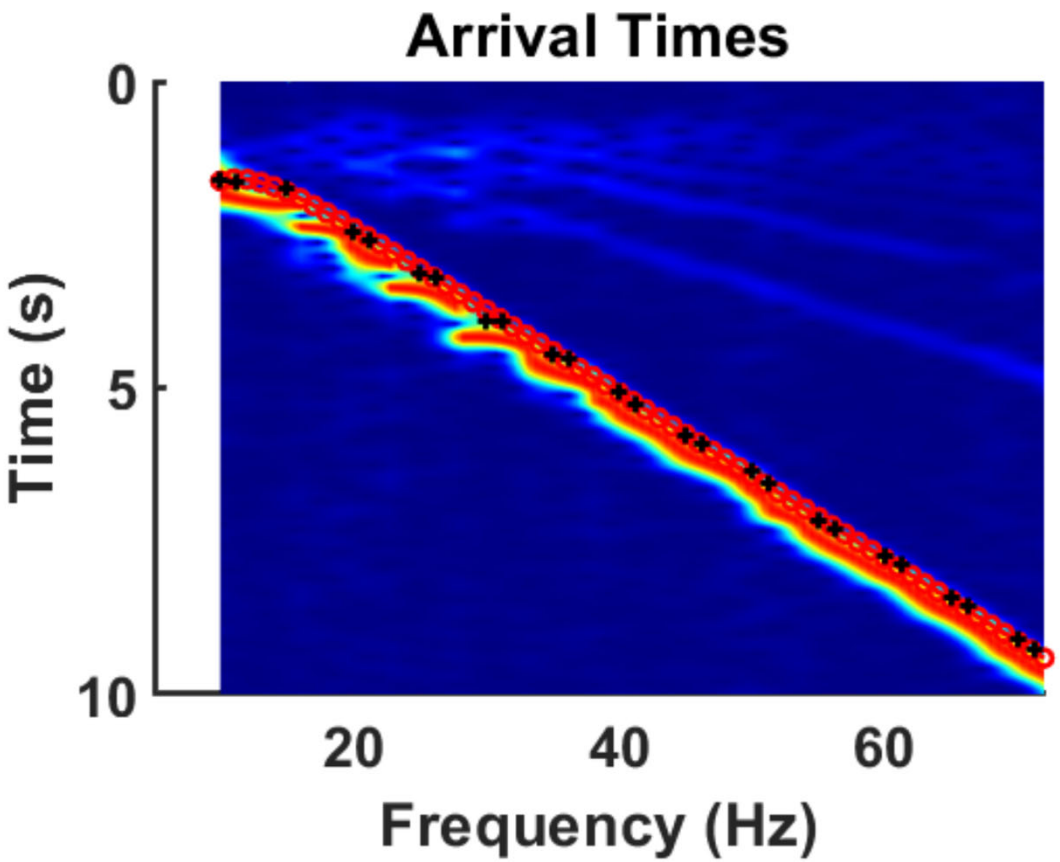


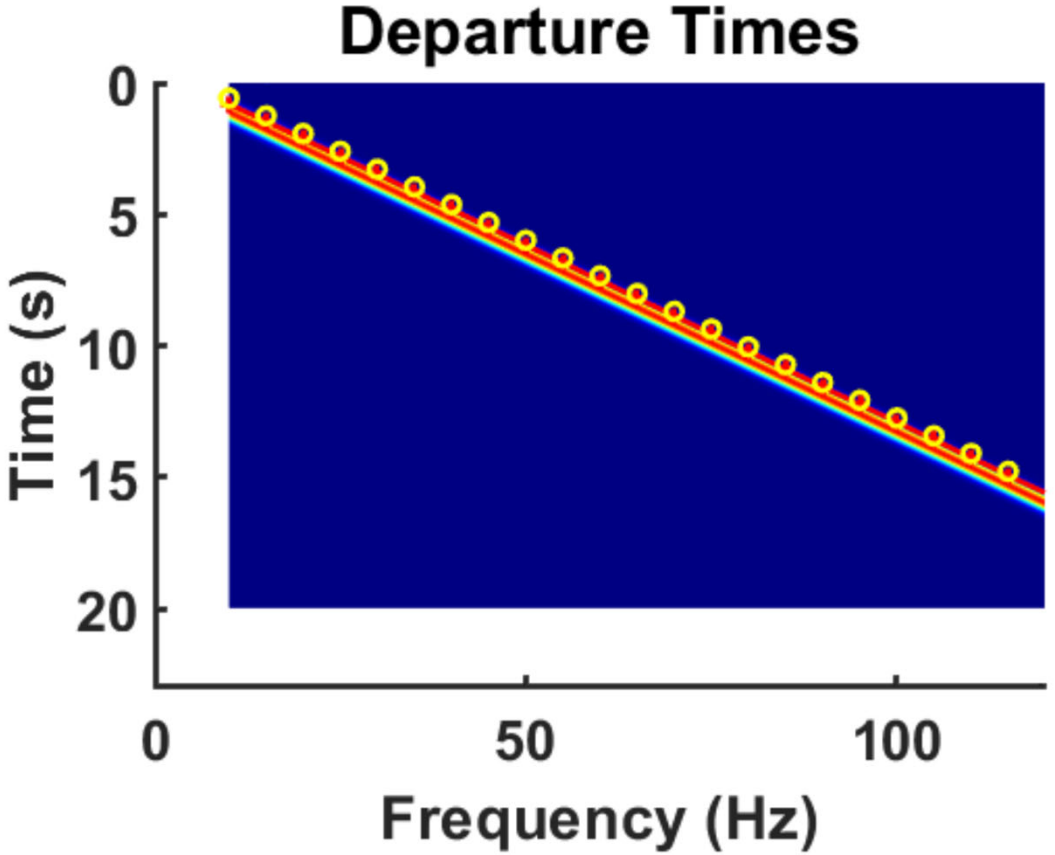






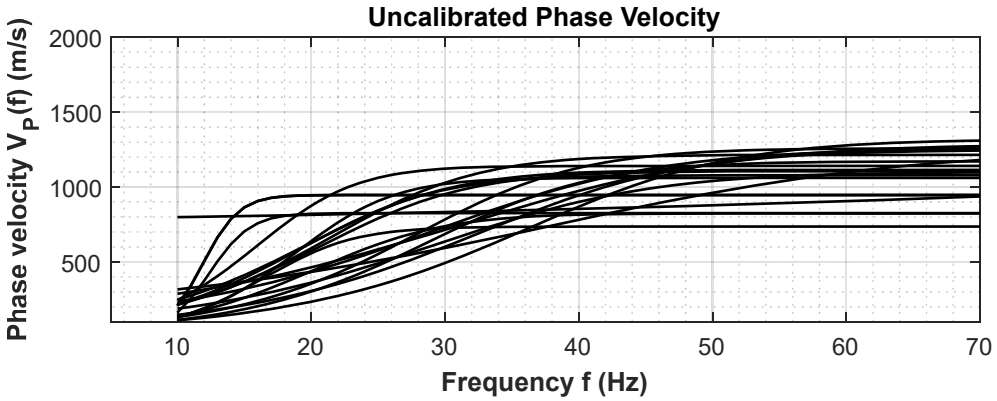
Automatic Picking procedure: Modified Energy Ratio(MER)

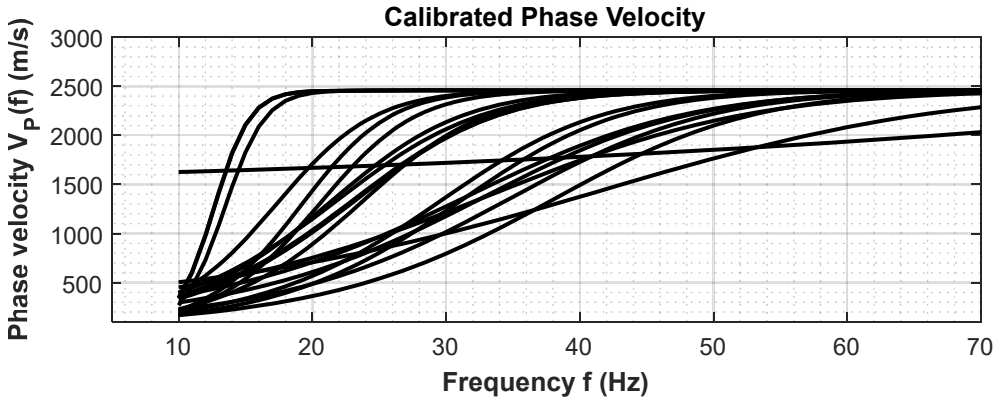


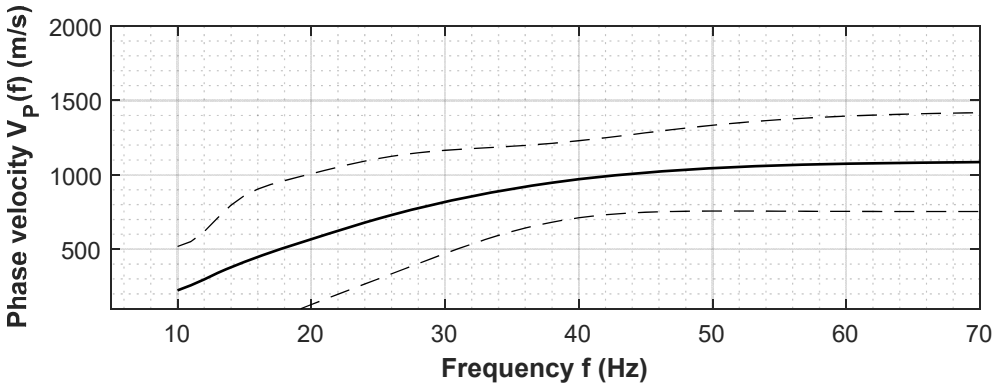


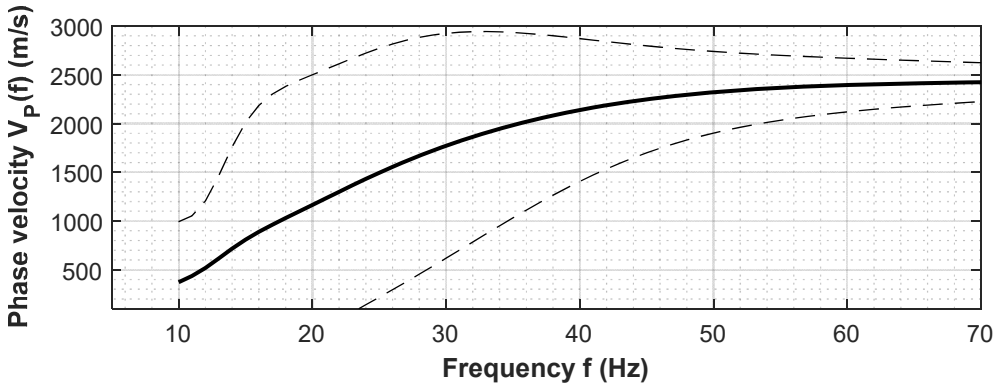
Estimating the calibrated phase velocity

$$V_{p(f)} = \frac{L}{T_{M(f)} - T_{s(f)} - T_{cal}}$$



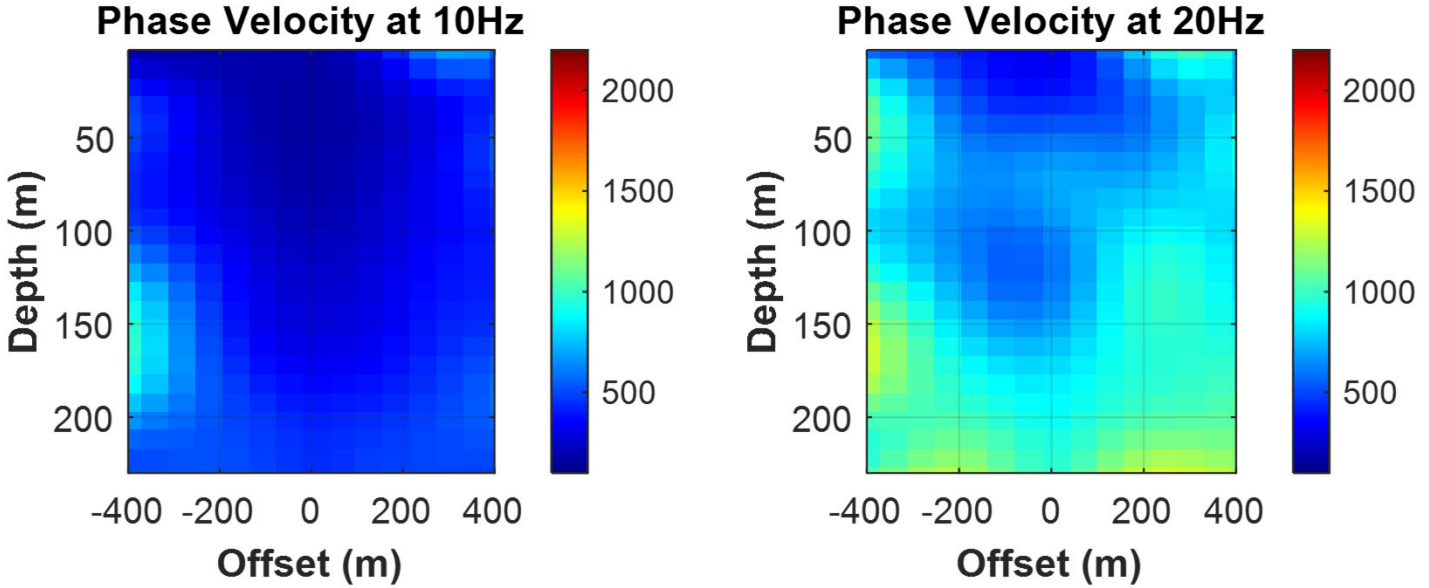


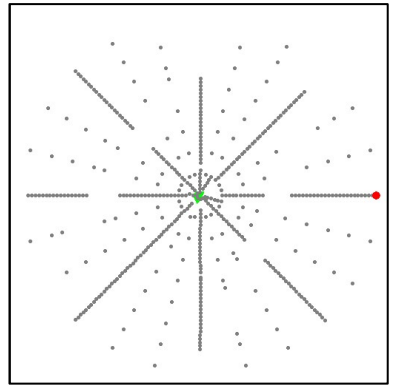


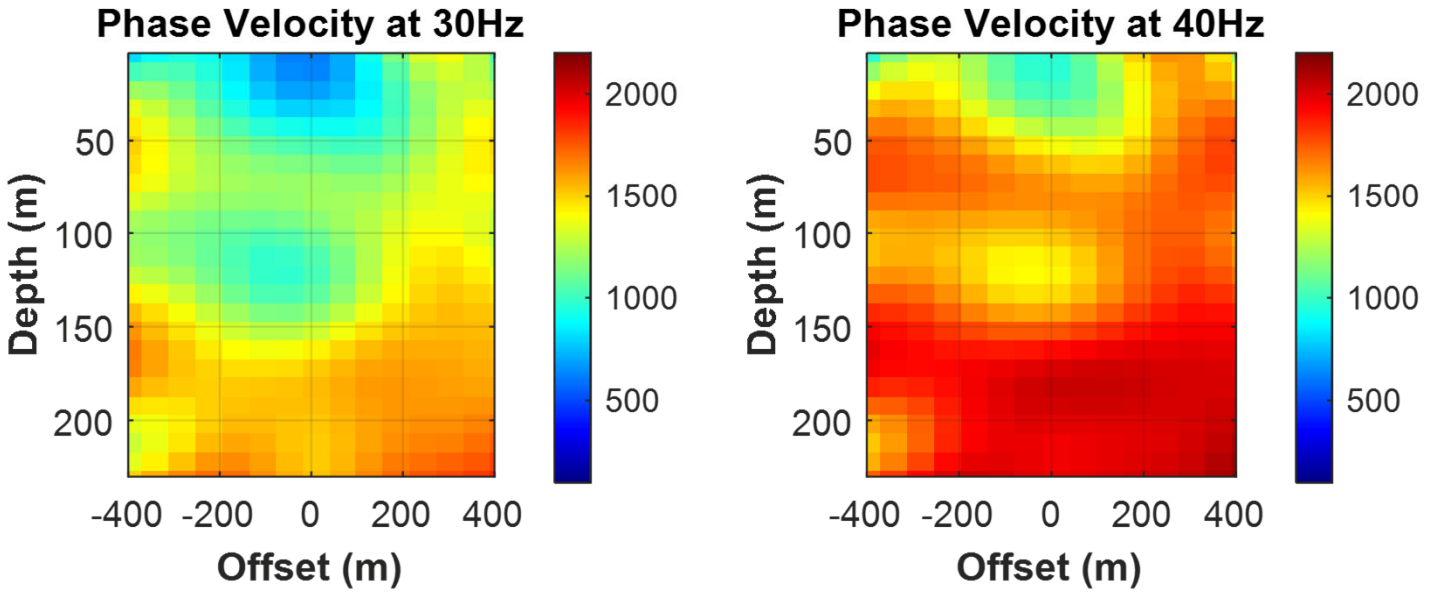


Depth 1-232m

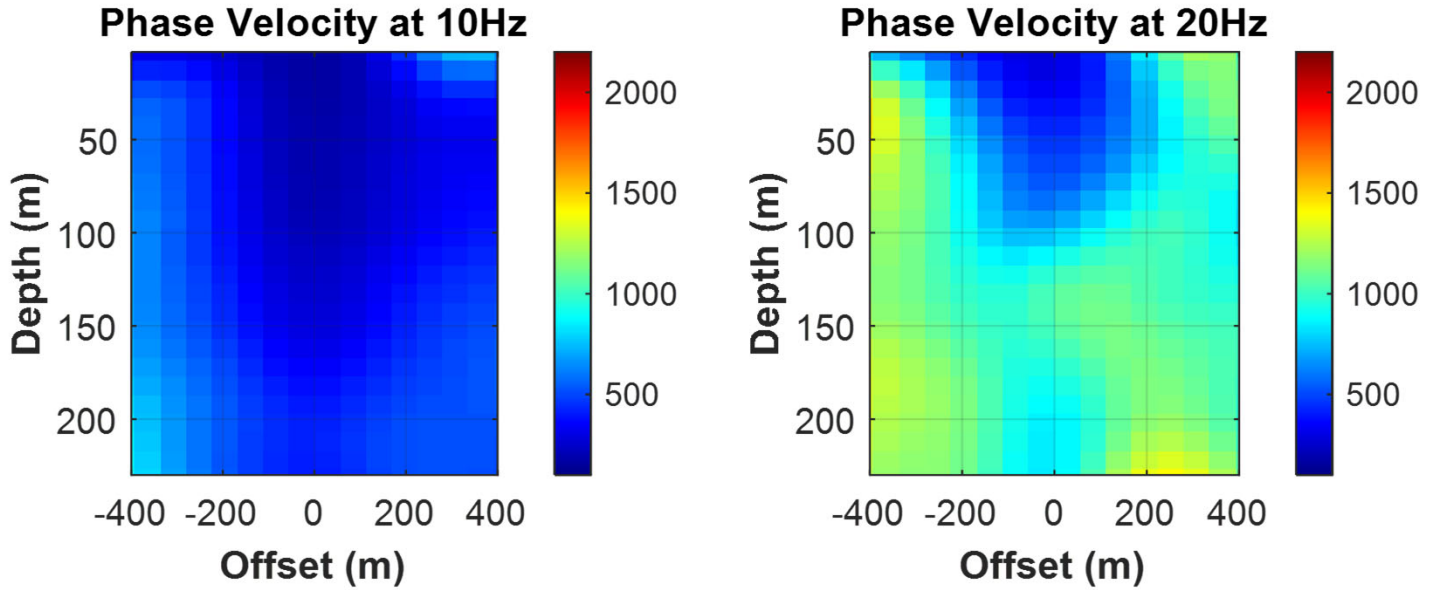
Phase velocity maps

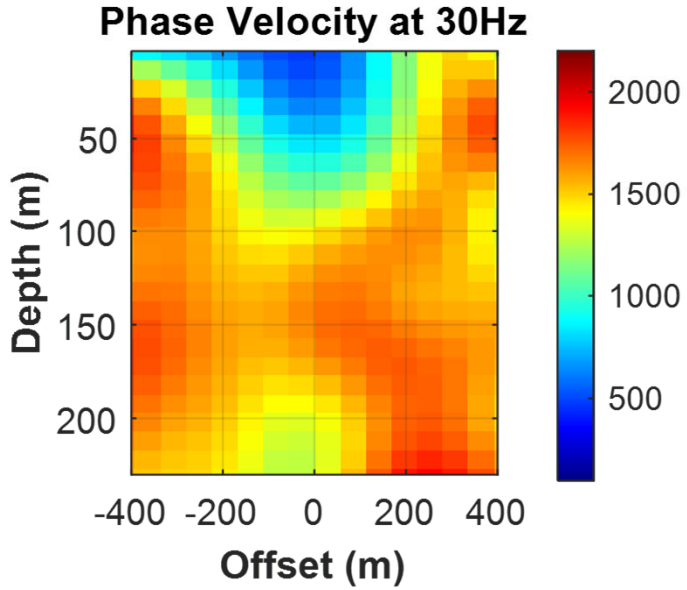


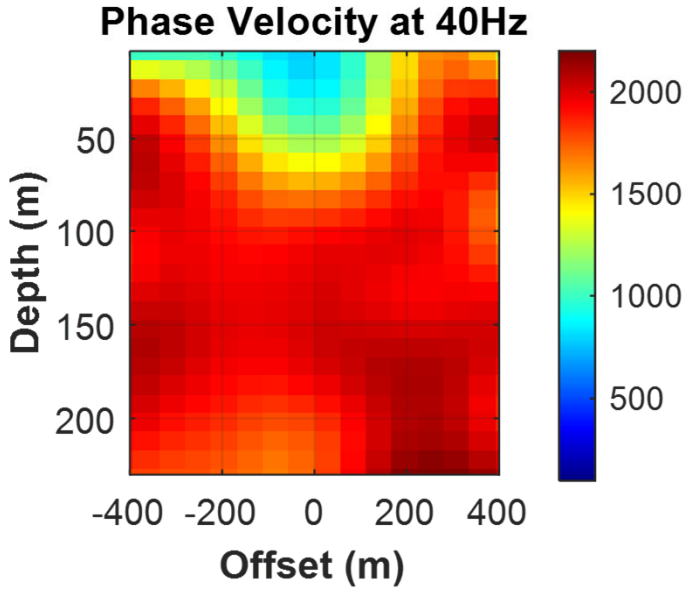


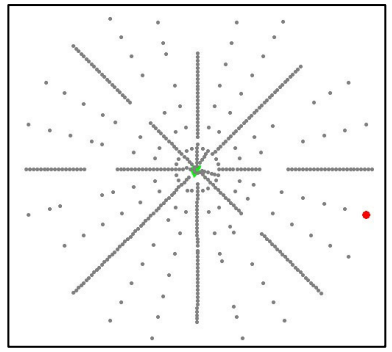


Phase velocity maps









Summary

- Analyzing the VSP datasets from the Newell County facility enhances understanding of the complex near-surface.
- Phase velocity changes with VSP line azimuth; spatial heterogeneity in attenuation/dispersion.
- Estimating the frequency-dependent phase velocities in the near-surface supports determining the Q-factor.
- Phase velocity estimates could be used as initial models for FWI
- Next steps: connect with VSP-FWI; analyze S wave data

Acknowledgement

- CREWES sponsors, faculty, and staff
- NSERC