# Core Carbon Storage and Monitoring Research (CCSMR):
# Task 5 – Monitoring subsurface CO2 with Seismic ambient noise

FWP-ESD 14095

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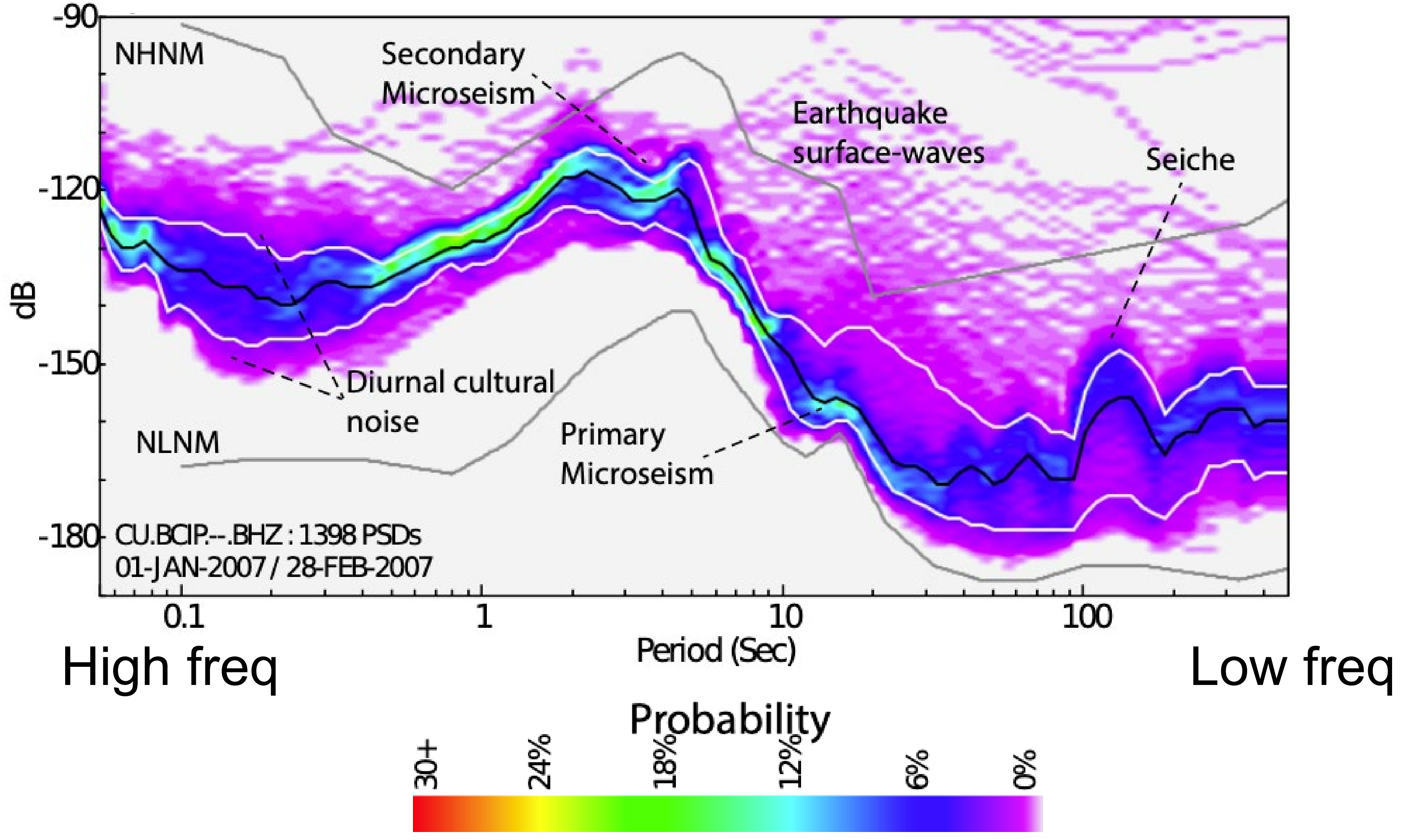
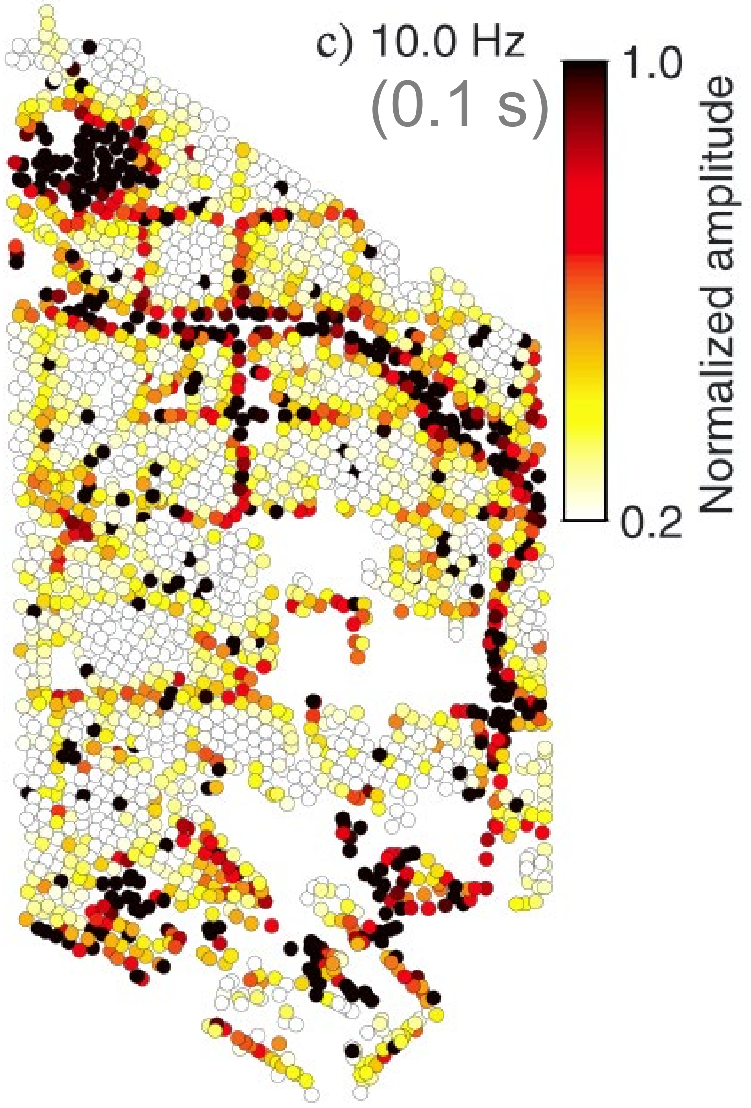
(LBNL)

# What is ambient noise?




Nakata et al., 2019, CUP

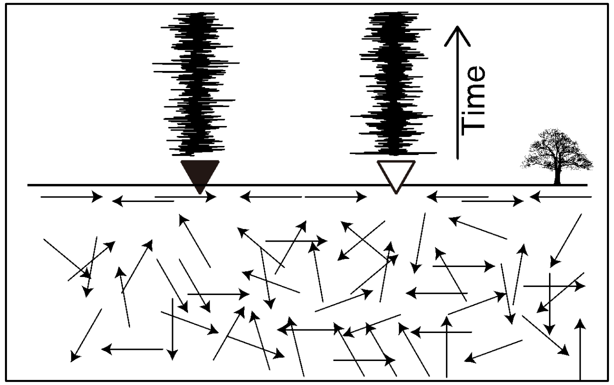



Nakata et al., 2015, JGR

# Ambient-noise imaging and monitoring

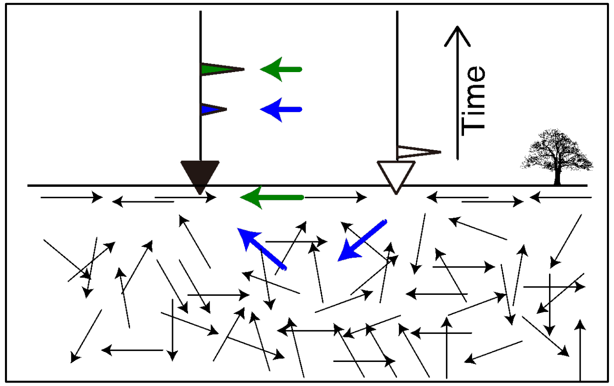
Ambient seismic wavefields are sensitive to subsurface structure and its time-lapse changes, but low-cost signals without using manmade sources.

Concept of ambient noise wavefield extraction




Observed random wavefield

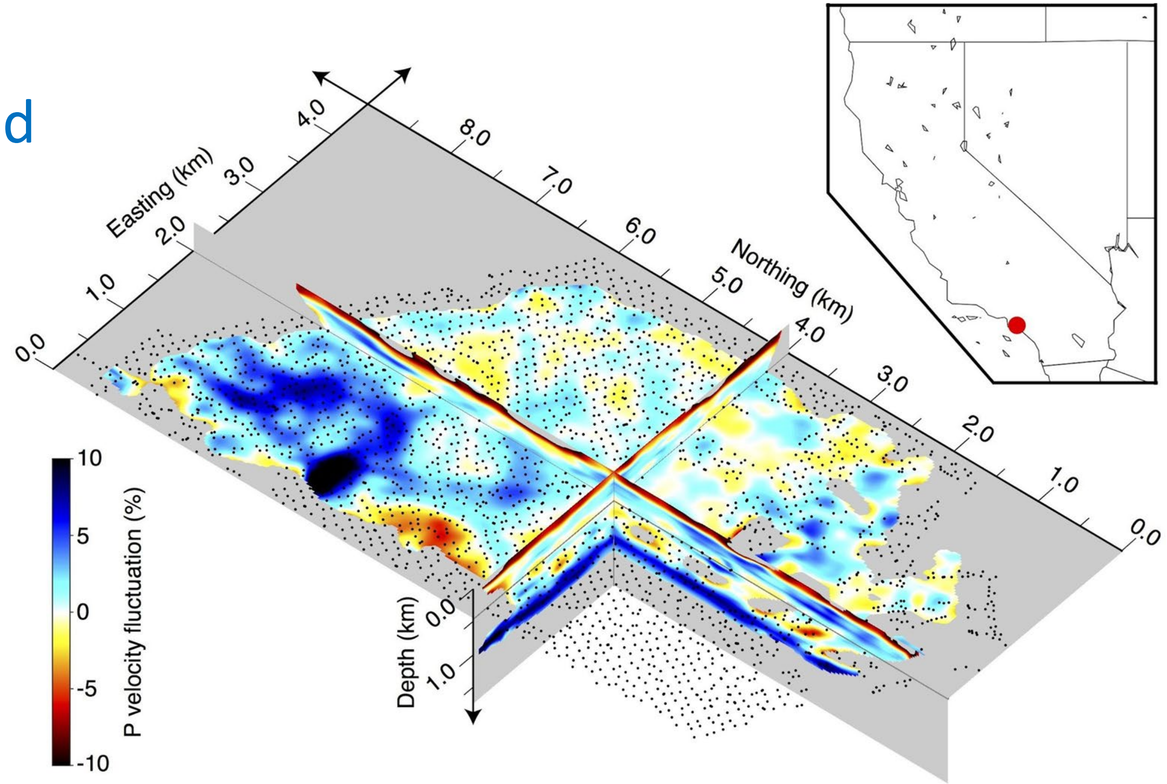
Signal processing




Extracted coherent waves for imaging & monitoring

Nakata et al., 2019, CUP

High-resolution subsurface imaging with ambient noise

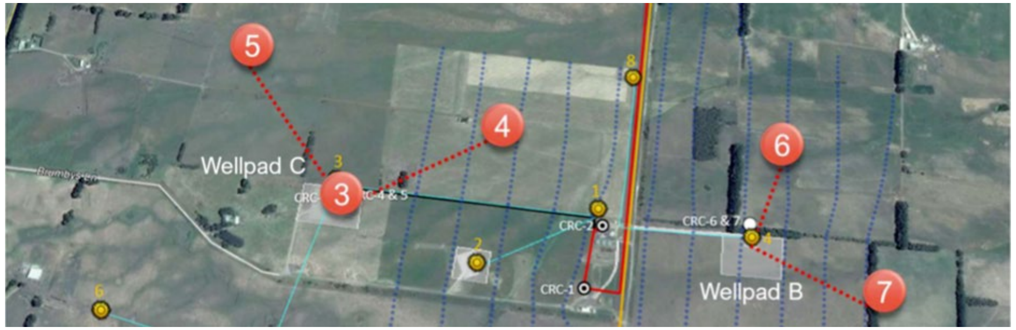


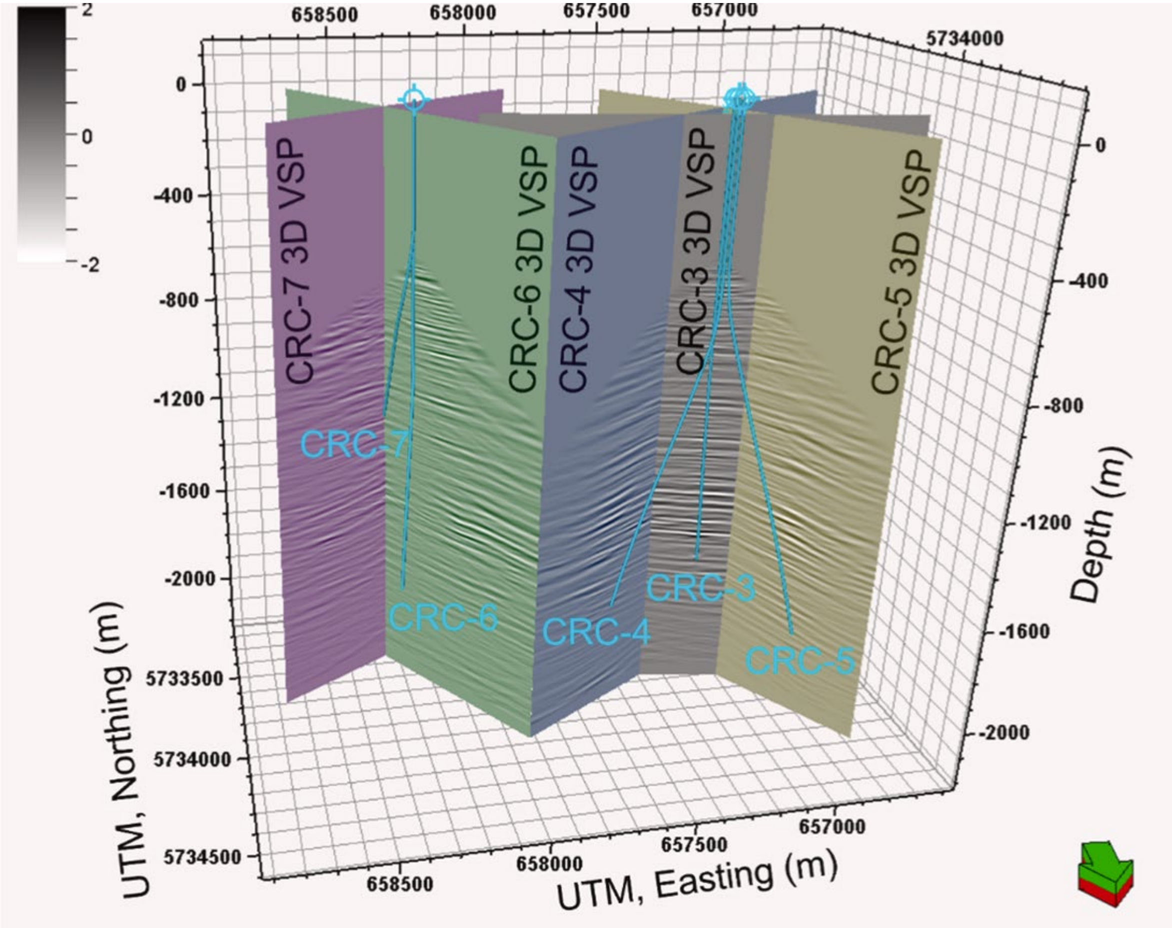

Nakata et al., 2015, JGR

# Field dataset

- Otway Test Site in Australia
  - Multiple fiber-instrumented wells
  - Continuous recording of acoustic motion (DAS)
    - One-day data is processed (baseline data).
    - Data recorded in CRC5, CRC6, CRC7 and surface.
    - 250GB/day.
  - 5-m receiver spacing
  - 10-m gauge length

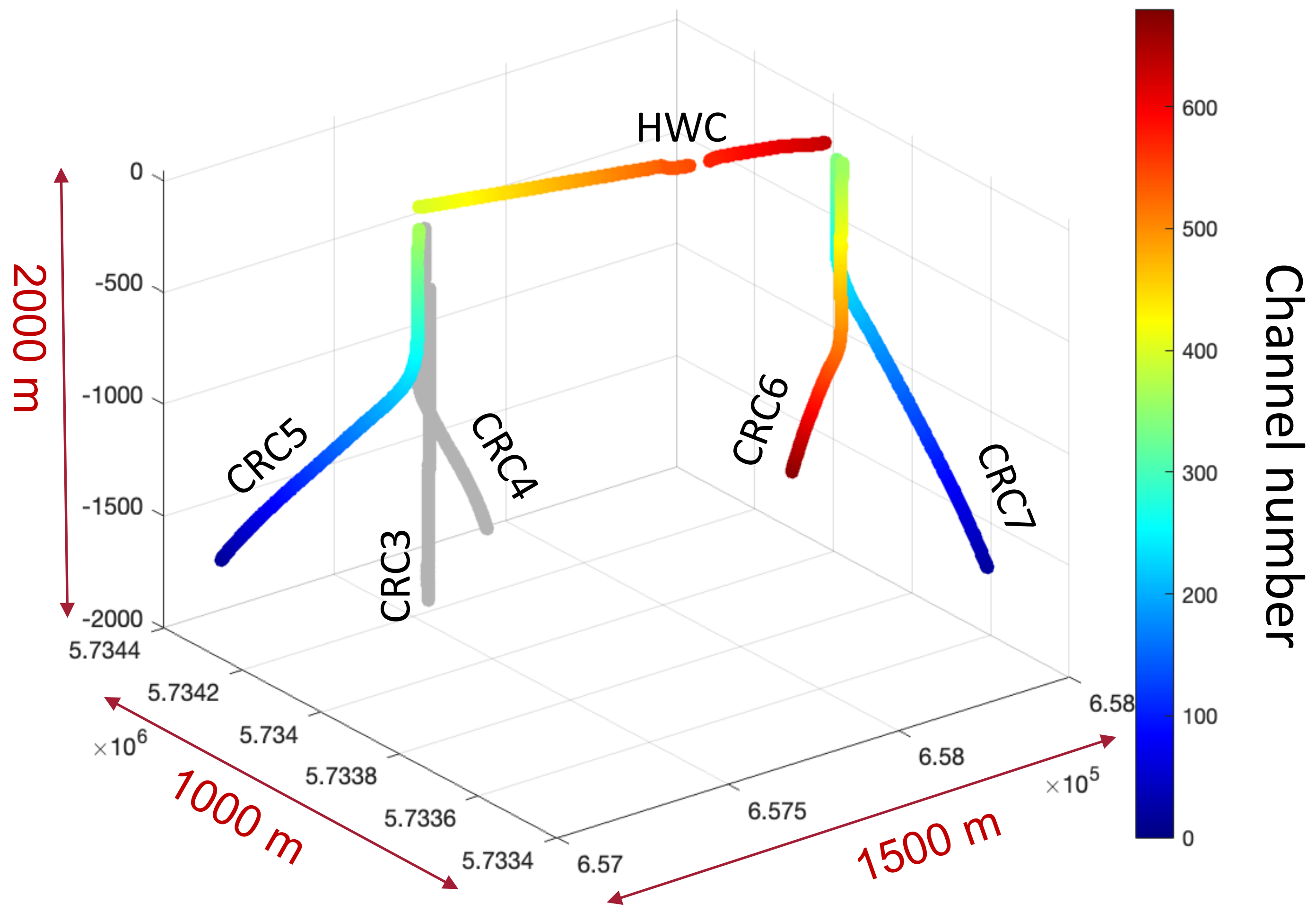
- We’re working on CabonSAFE sites.



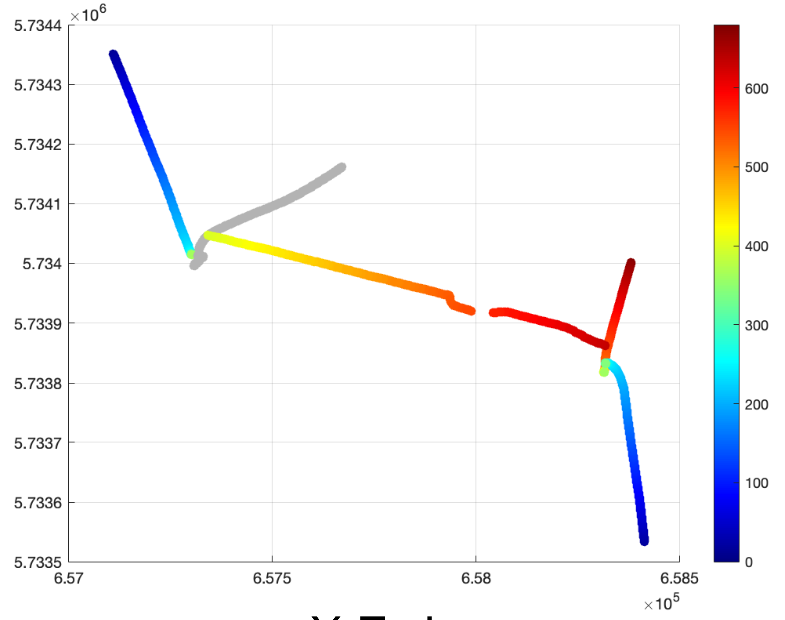




Barraclough et al., 2022; Yurikov et al., 2022

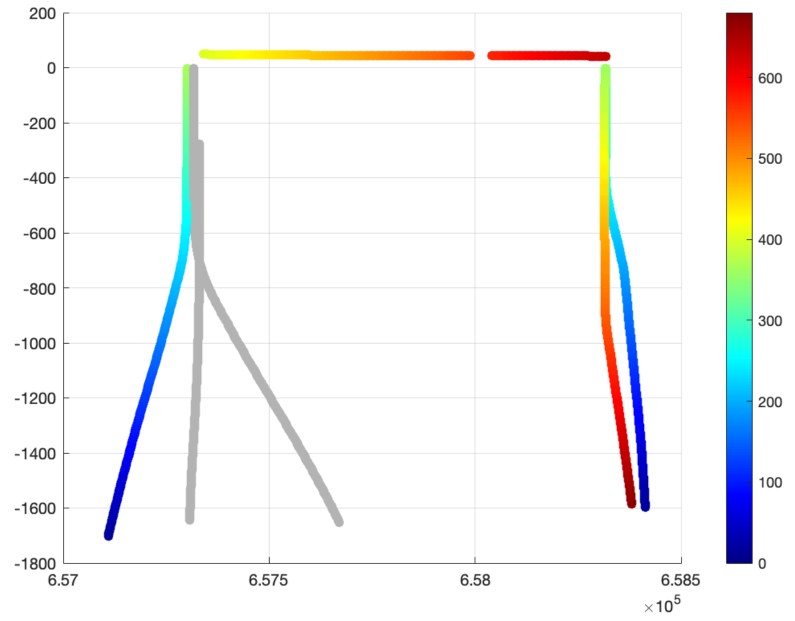
# DAS cable trajectory



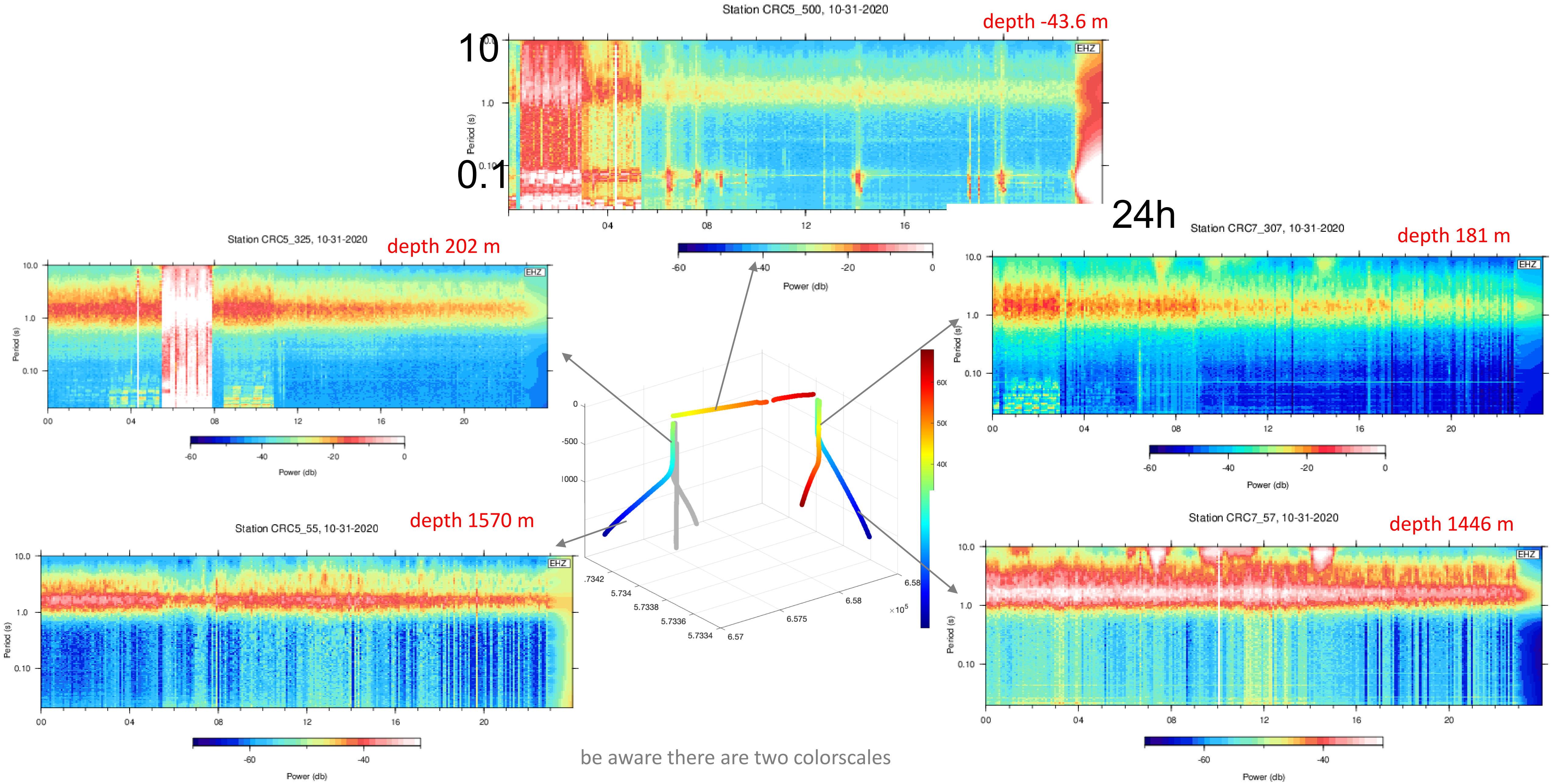

X-Y view



X-Z view

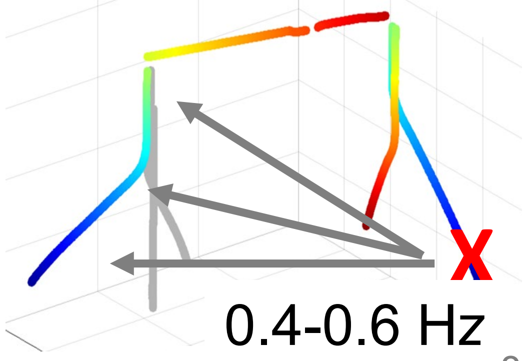


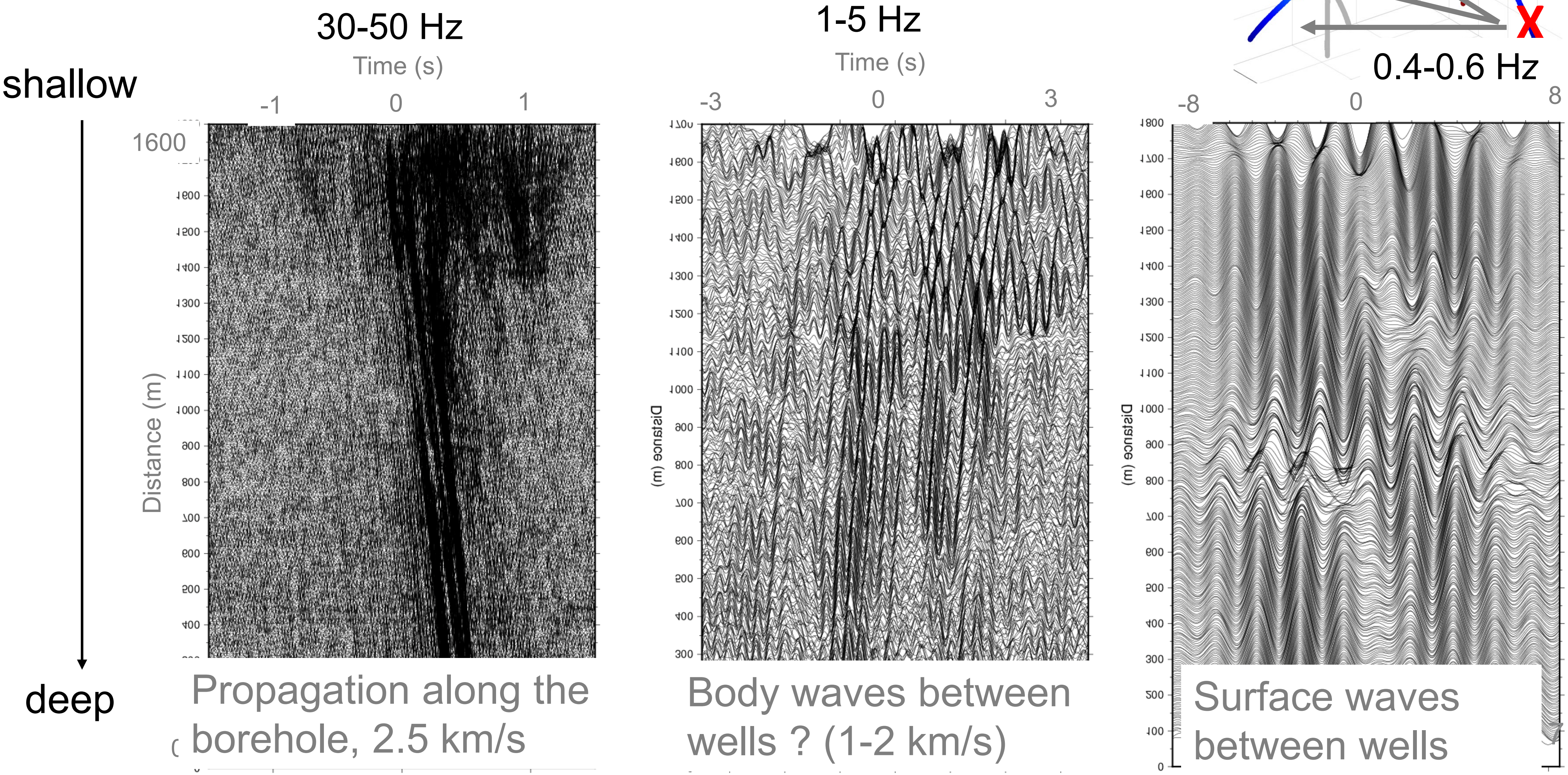
# Power spectra show depth dependencies and noisy band.




be aware there are two colorscales

# We can extract clear wave propagation between wells after ambient noise correlation.



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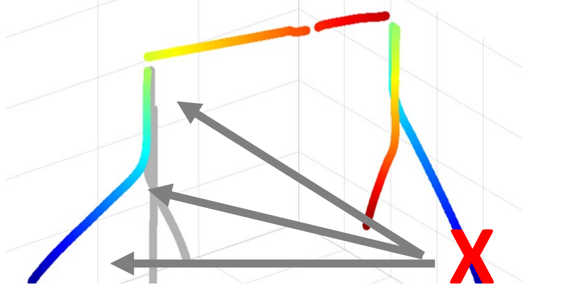

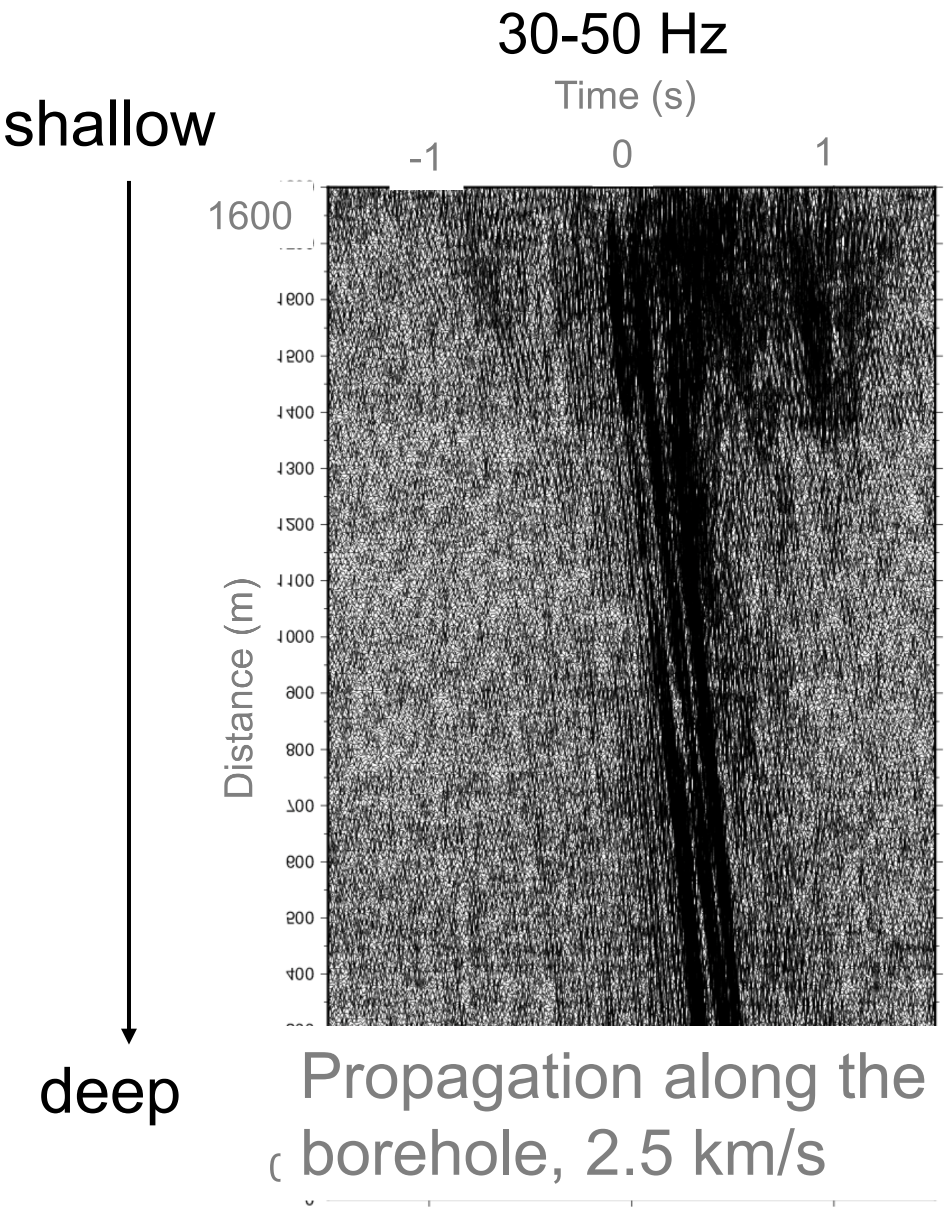


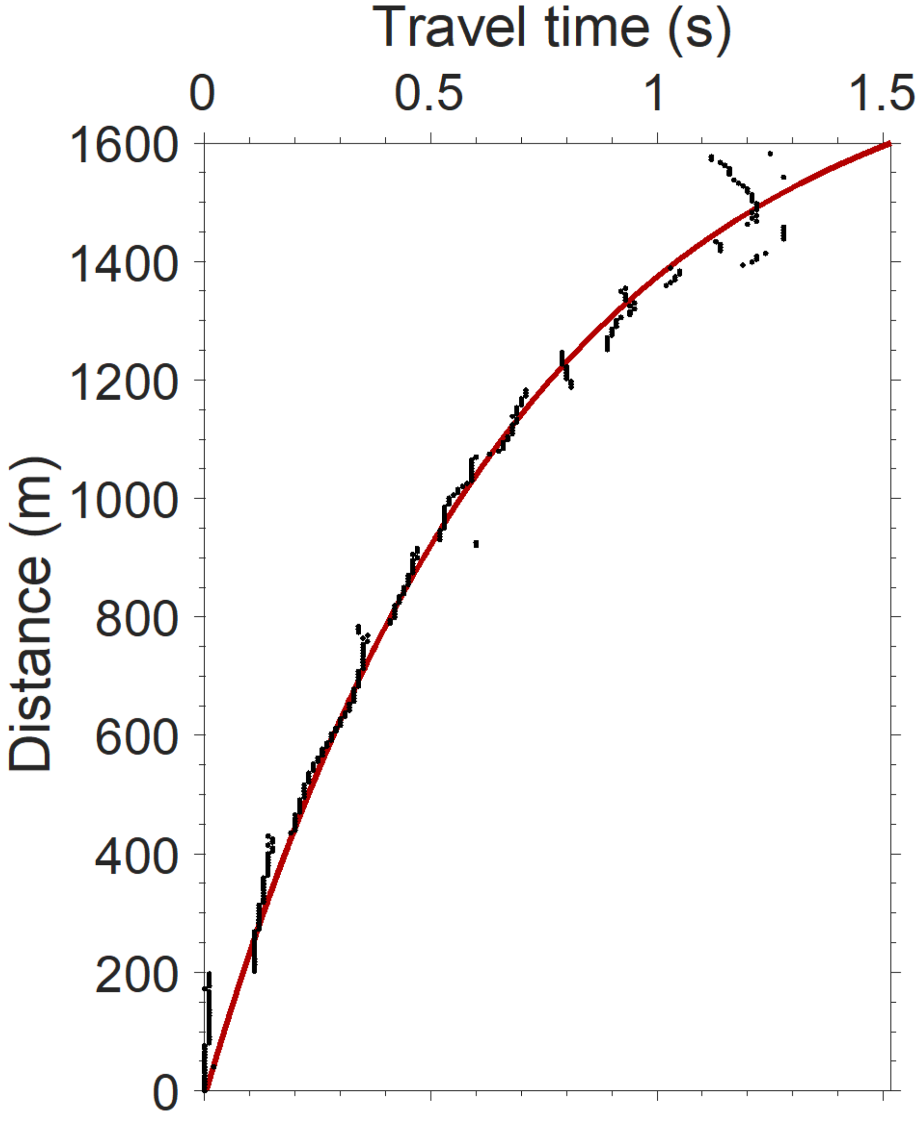


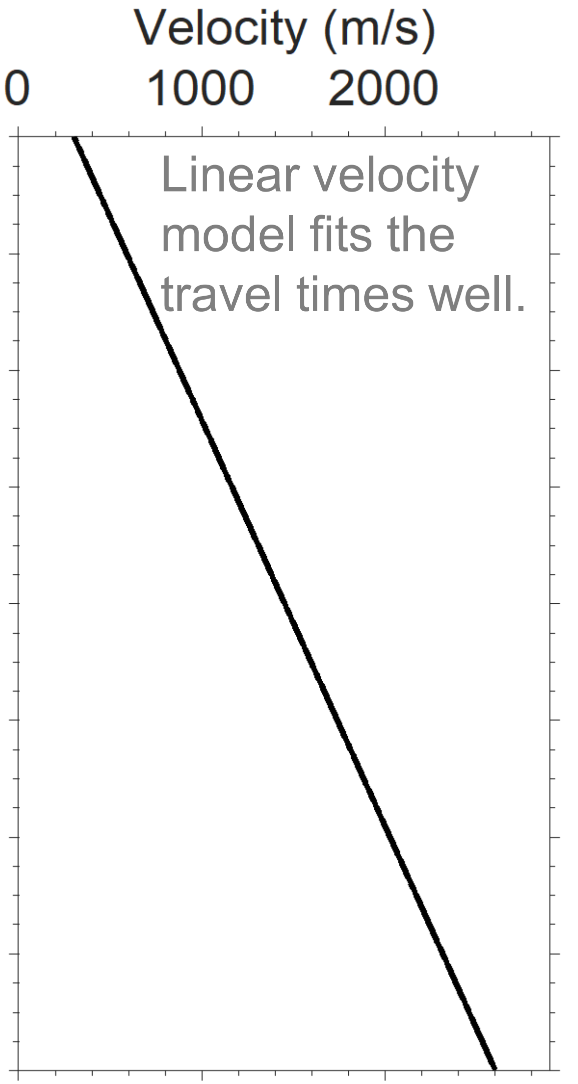

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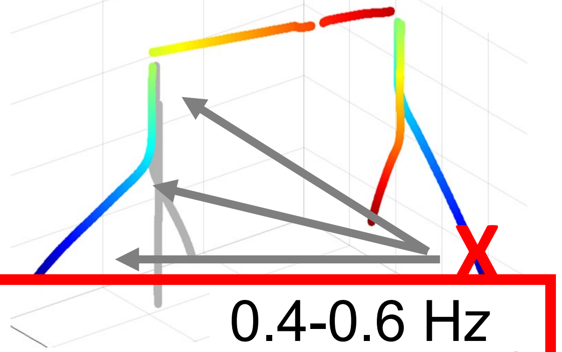
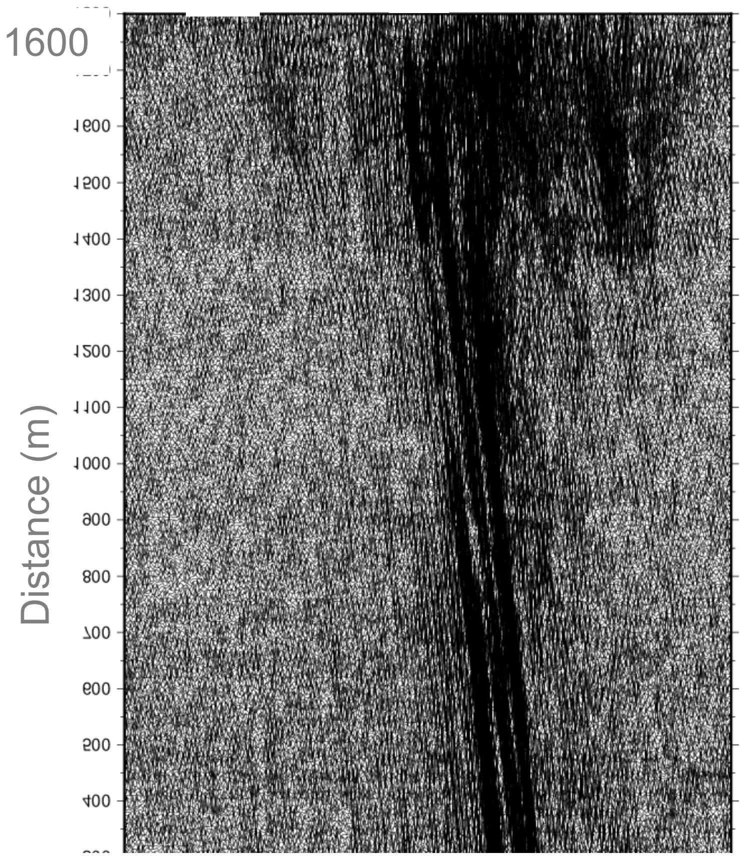


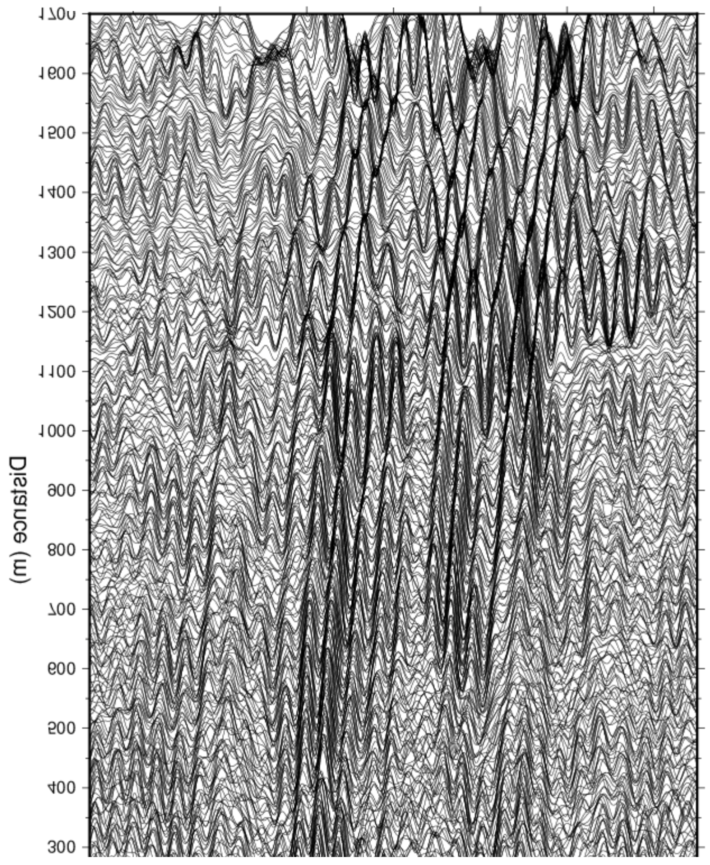
shallow

30-50 Hz



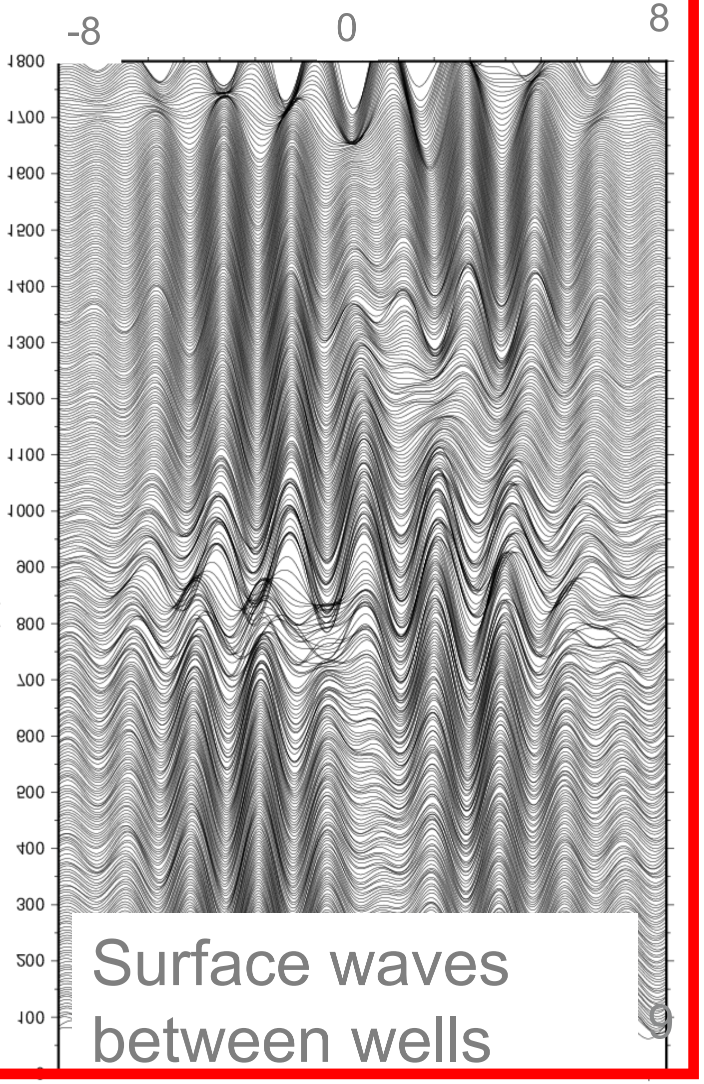

Propagation along the borehole, 2.5 km/s

1-5 Hz




Body waves between wells ? (1-2 km/s)

0.4-0.6 Hz

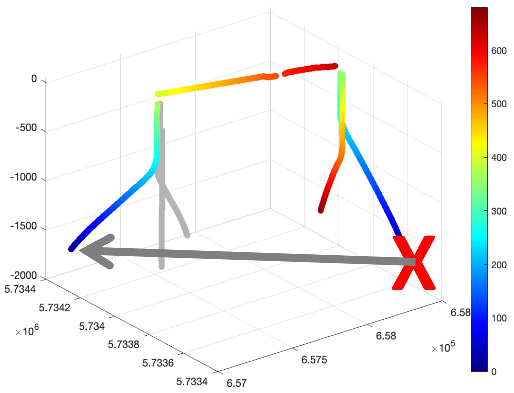



Surface waves between wells

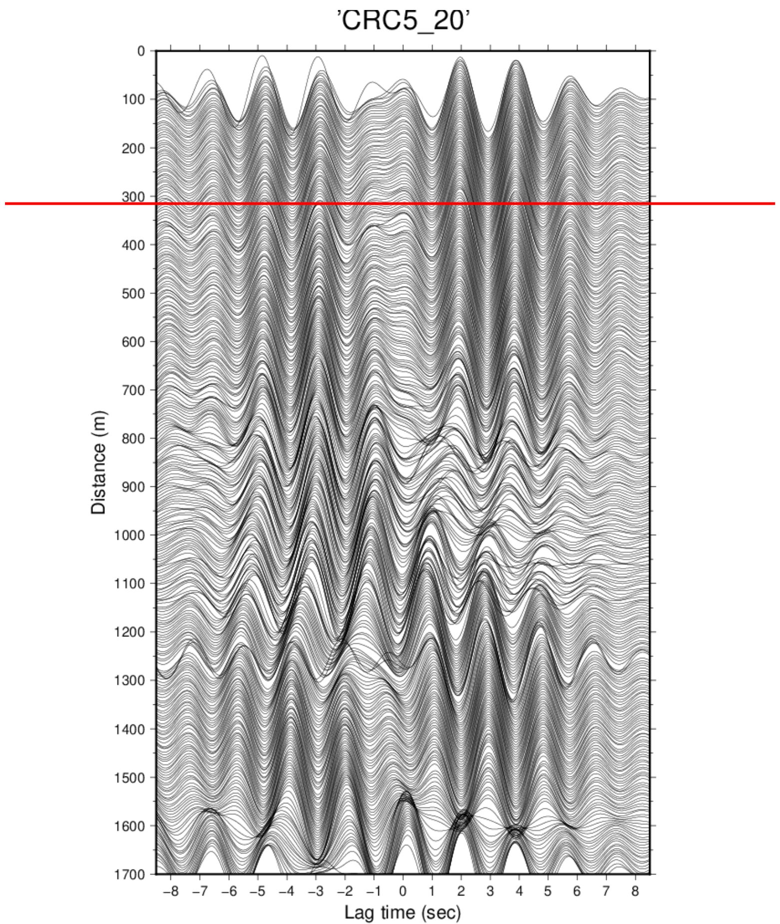
deep

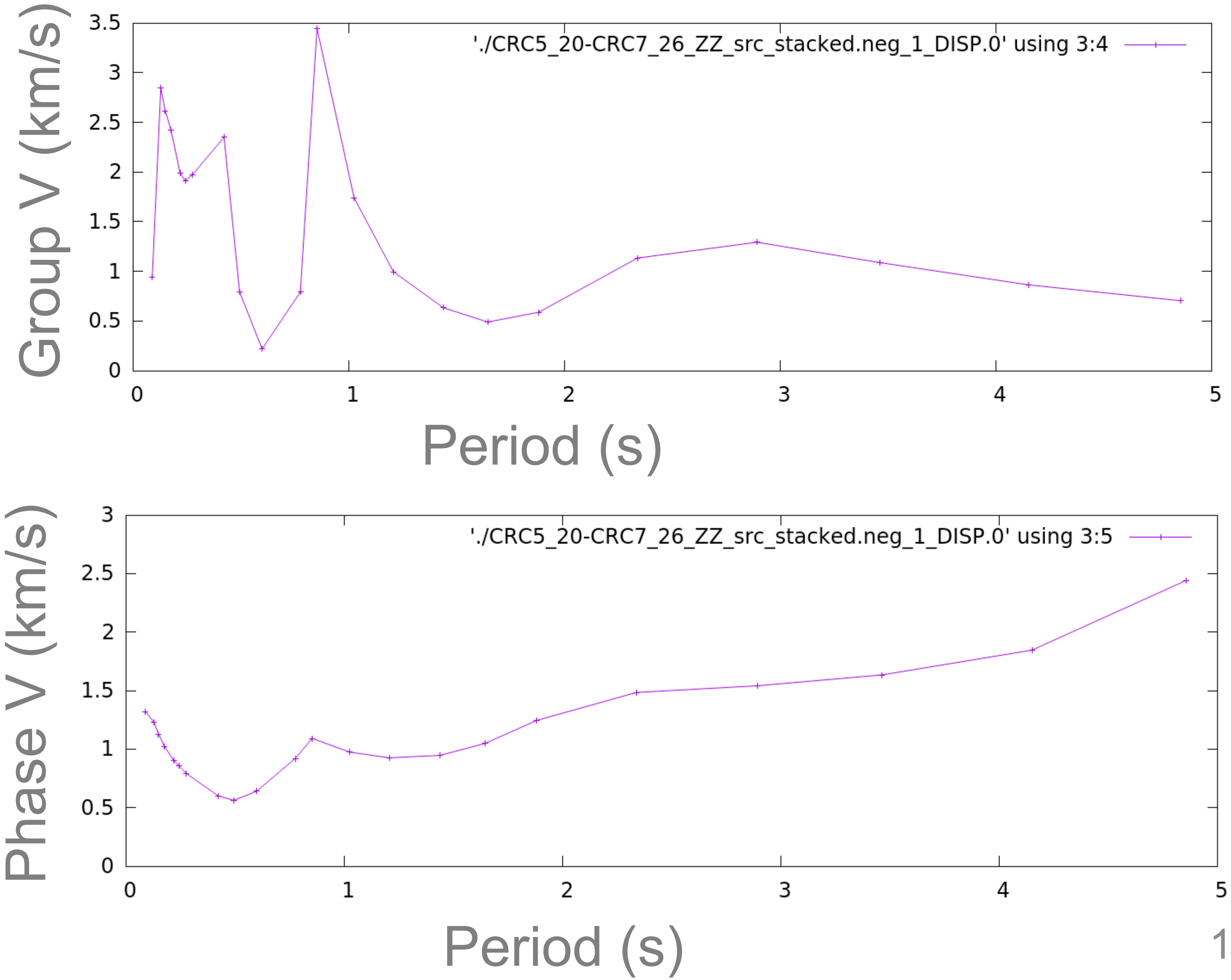
# CRC7-CRC5: Surface-wave dispersion analysis

1.53 km distance, search 0.1-4 km/s in FTAN



0.4-0.6Hz

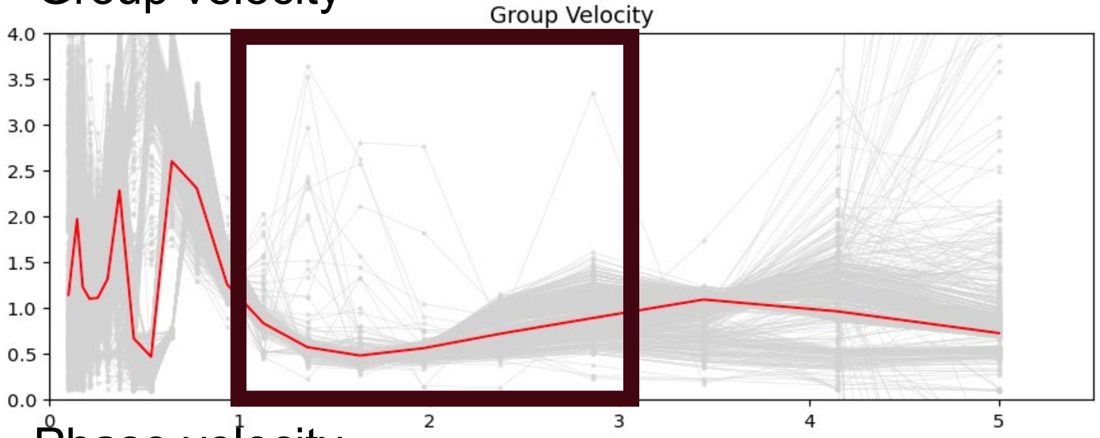


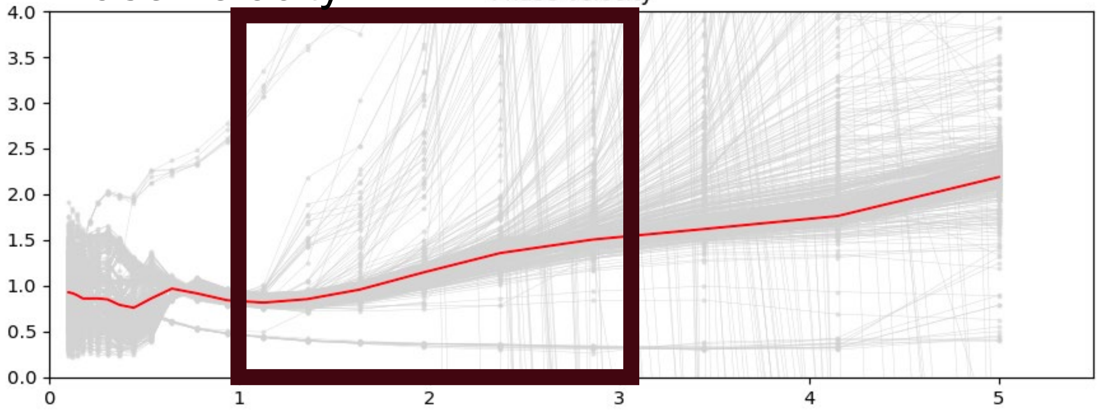
# We only use good quality frequency bands for inversion.

Negative lags

Group velocity

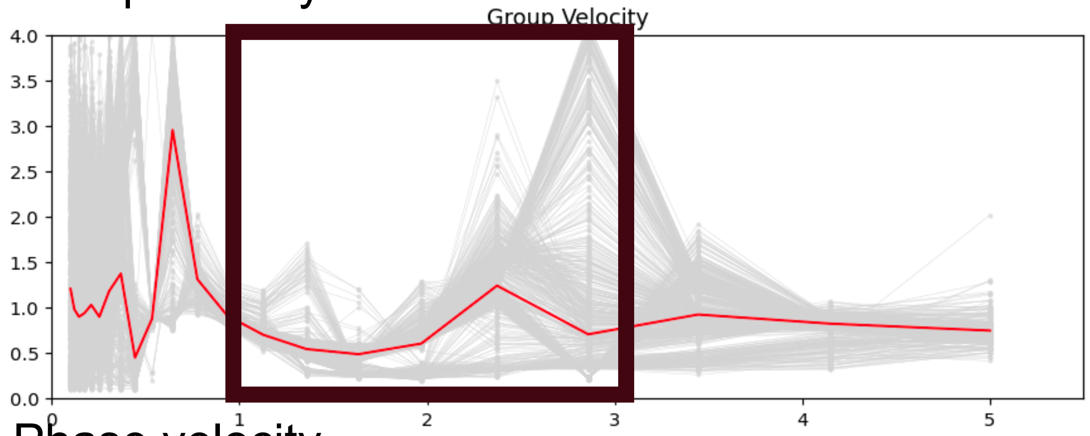



Phase velocity

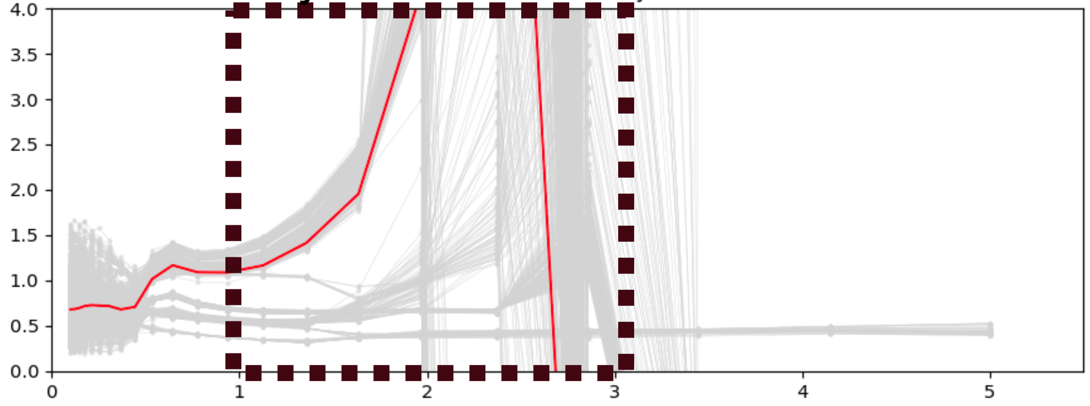



Positive lags

Group velocity




Phase velocity



# Neighbourhood Algorithm inversion

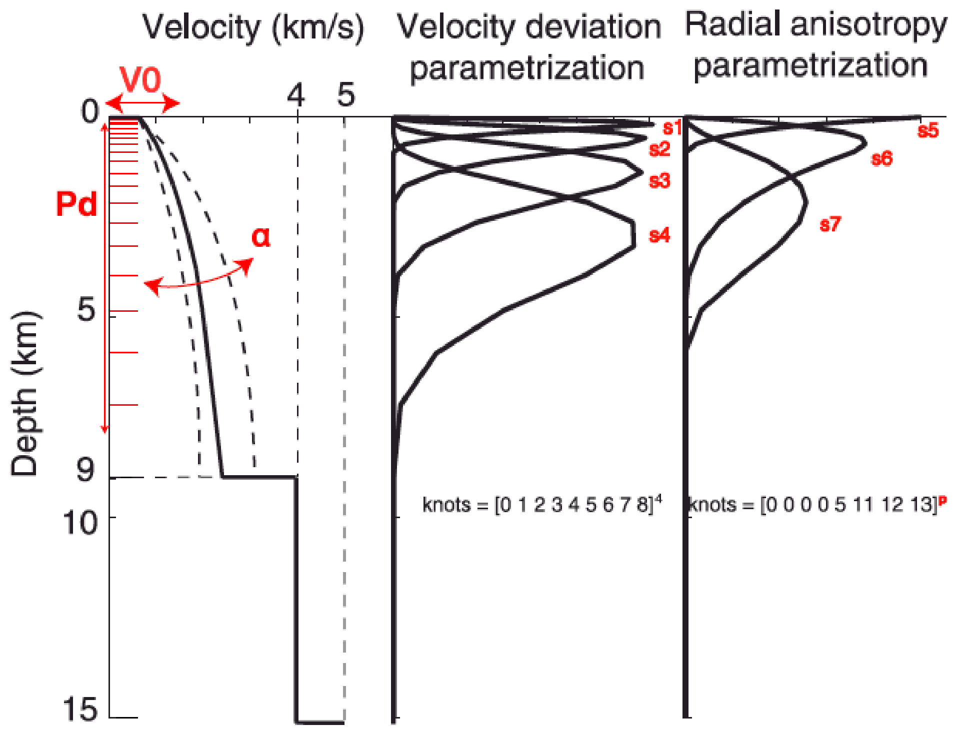
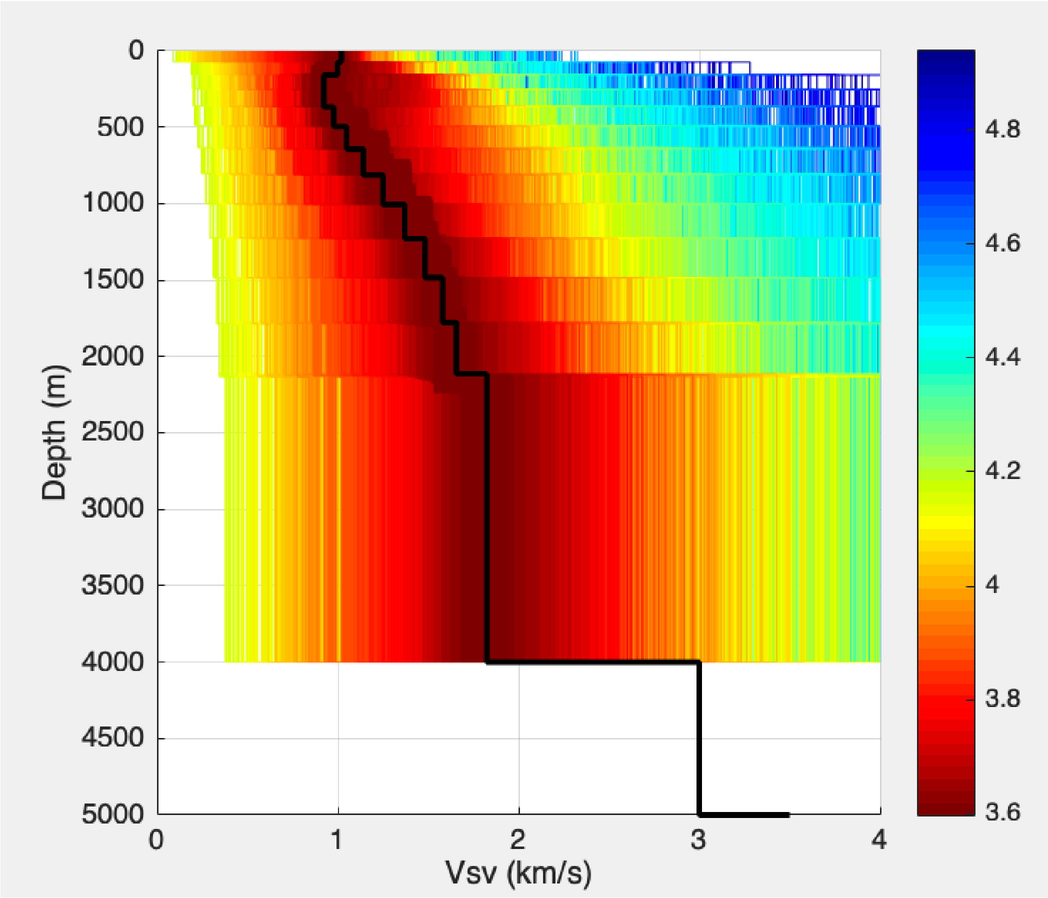



**Figure 10.** Model parameterization including 11 parameters: (1) $P_d$ controls the layer depths, (2) $V_0$, surface velocity, (3) $\alpha$, the curvature of the velocity profile, (4–7) cubic B spline perturbations to the power law $S$ wave velocity profiles, $S_1$ to $S_4$, (8–10) cubic B spline radial anisotropies, $S_5$ to $S_7$, and (11) a power $p$ for the anisotropy spline knots controlling the depth extent of the anisotropy.




Mordret et al., 2015

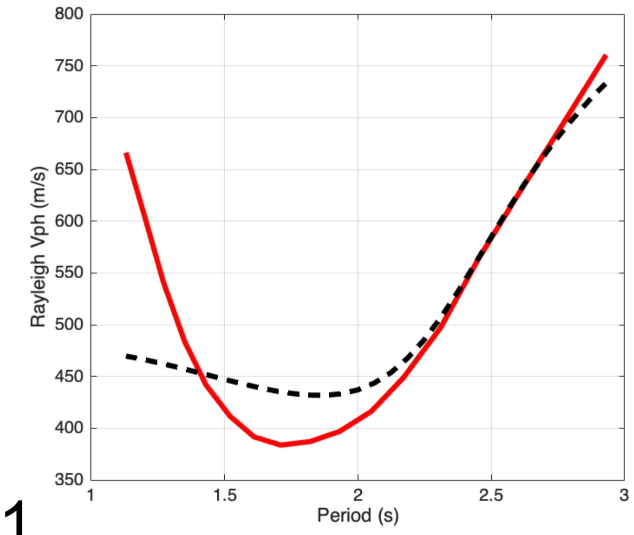
# Case 1 (Group dispersion at negative lag)

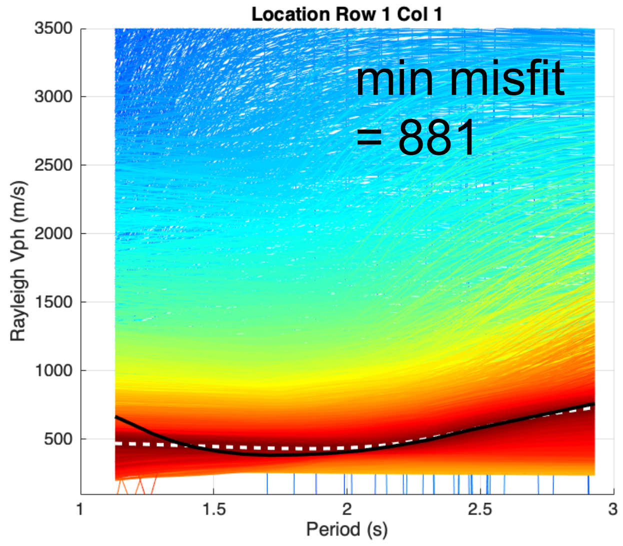
Mode 0

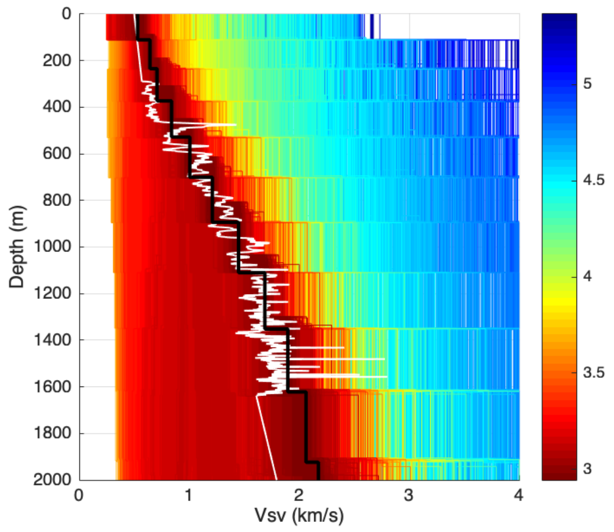
Red: data
Black: prediction

Color: misfit
Black: data, White prediction

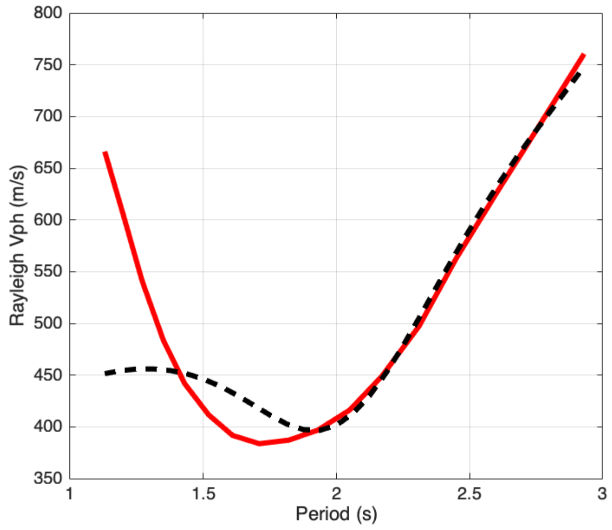
Black: final model (minimum misfit)
White: well-log Vs profile (Glubokovskikh et al., 2021)

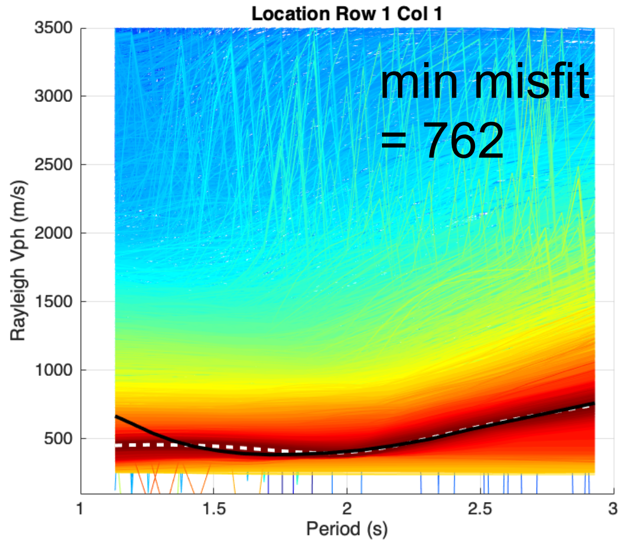


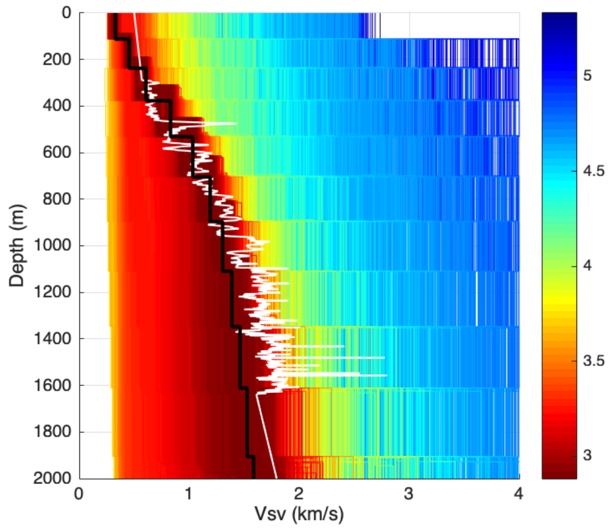




Mode1



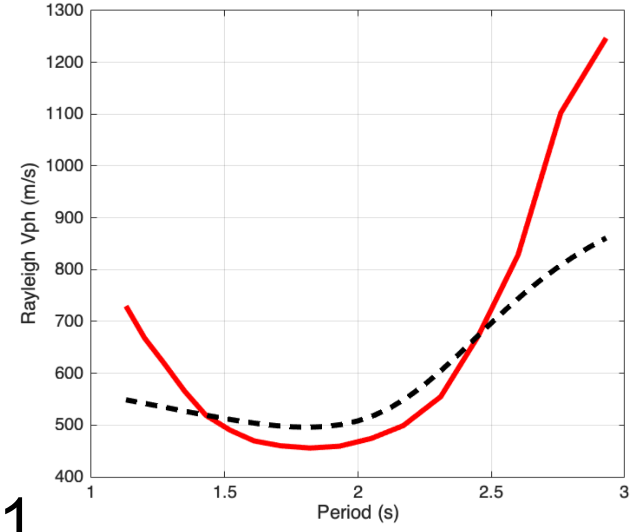
# Case 2 (Group dispersion at positive lag)

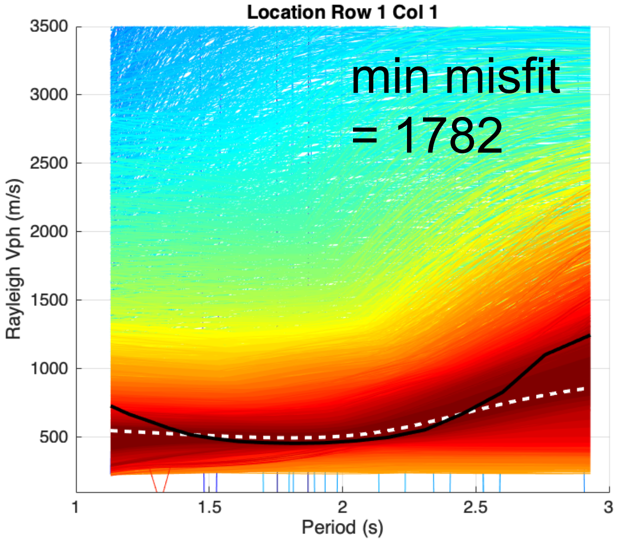
Mode 0

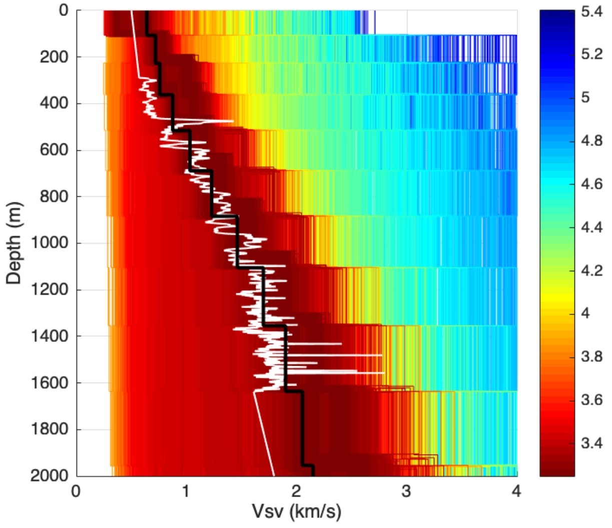
Red: data
Black: prediction

Color: misfit
Black: data, White prediction

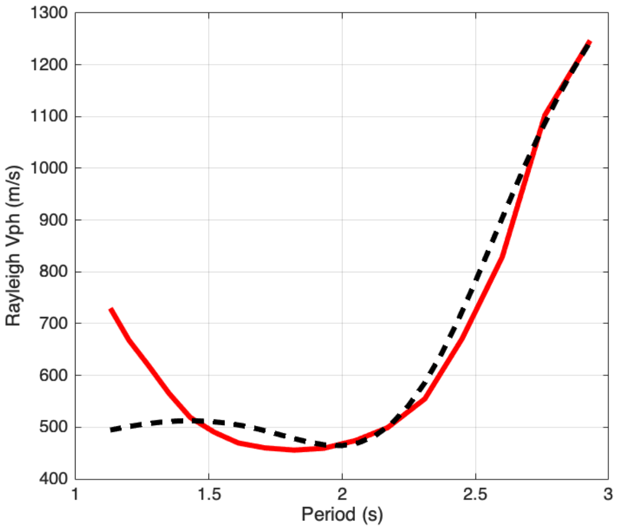
Black: final model (minimum misfit)
White: well-log Vs profile (Glubokovskikh et al., 2021)

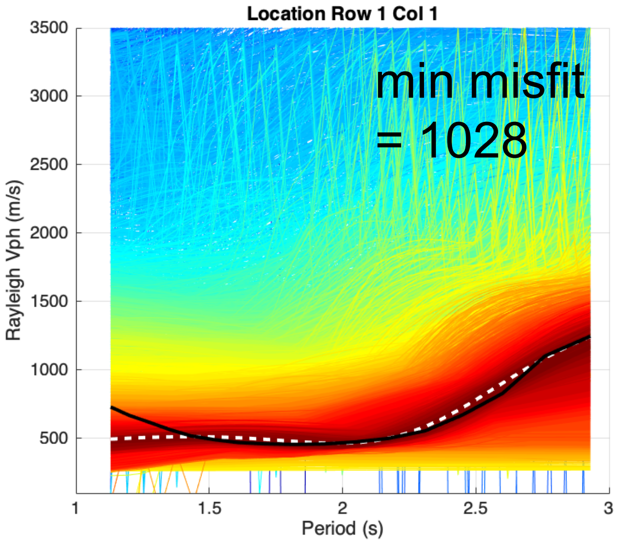


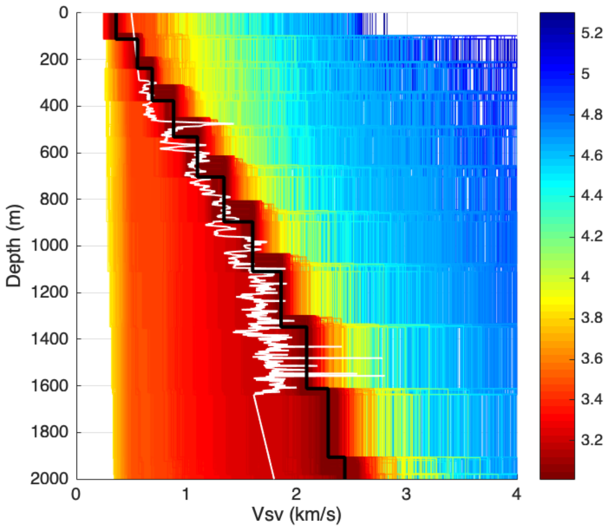




Mode1



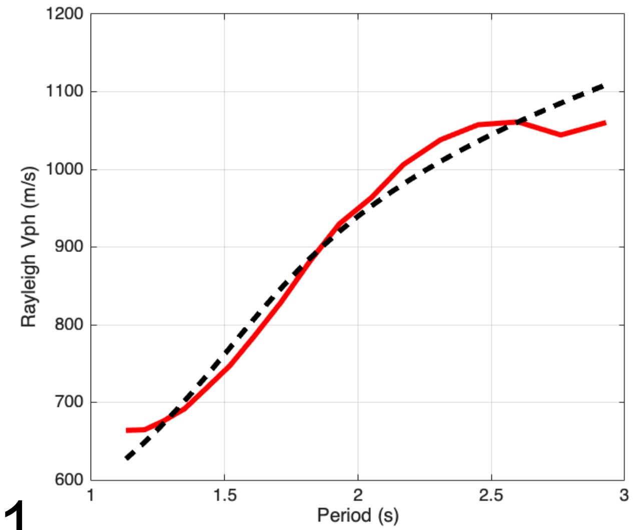



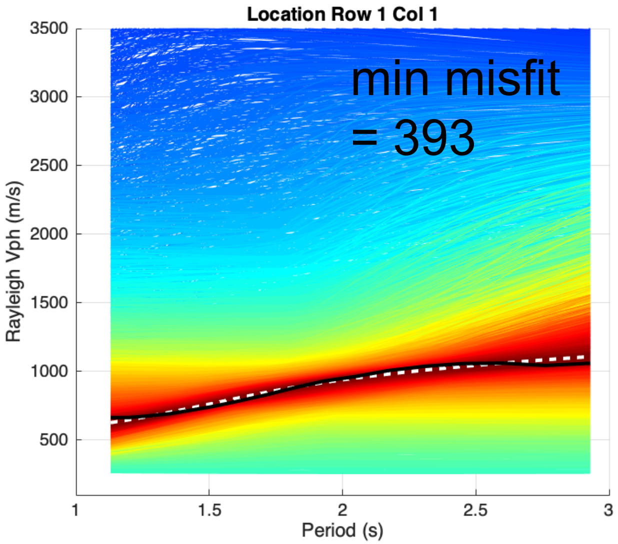
# Case 3 (Phase dispersion at negative lag)

Mode 0

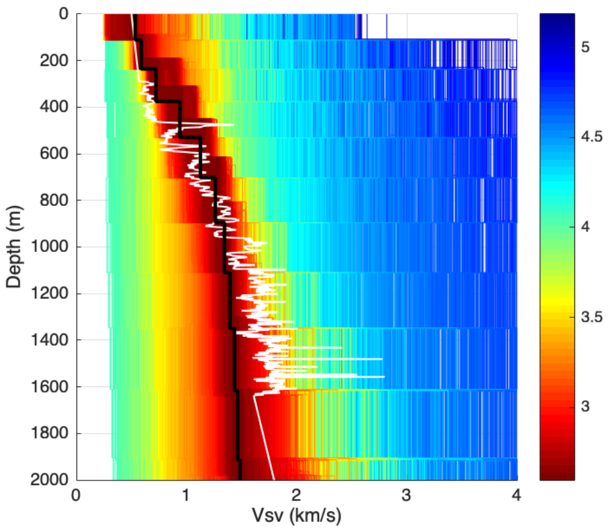
Red: data
Black: prediction



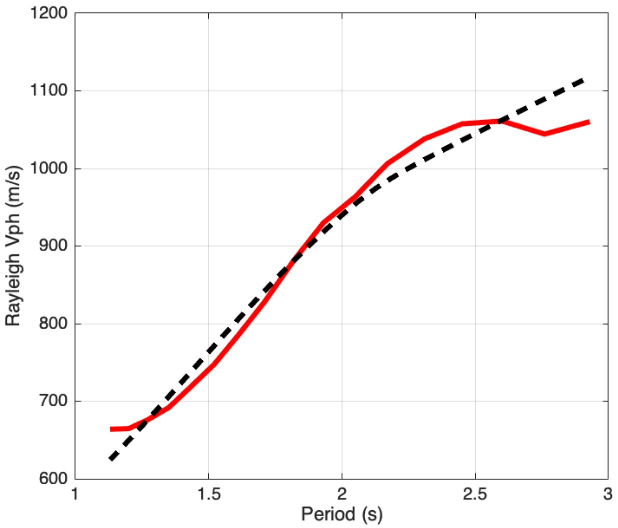

Color: misfit
Black: data, White prediction

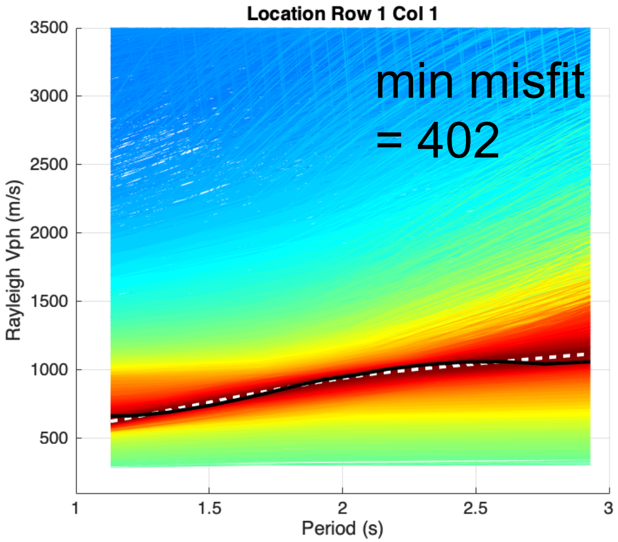


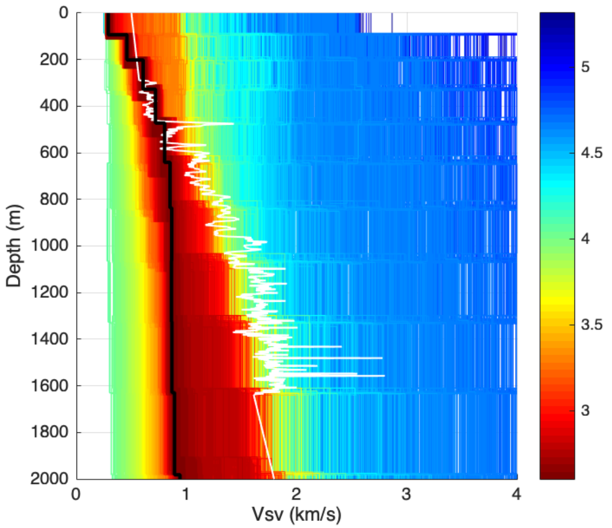

Black: final model (minimum misfit)
White: well-log Vs profile (Glubokovskikh et al., 2021)



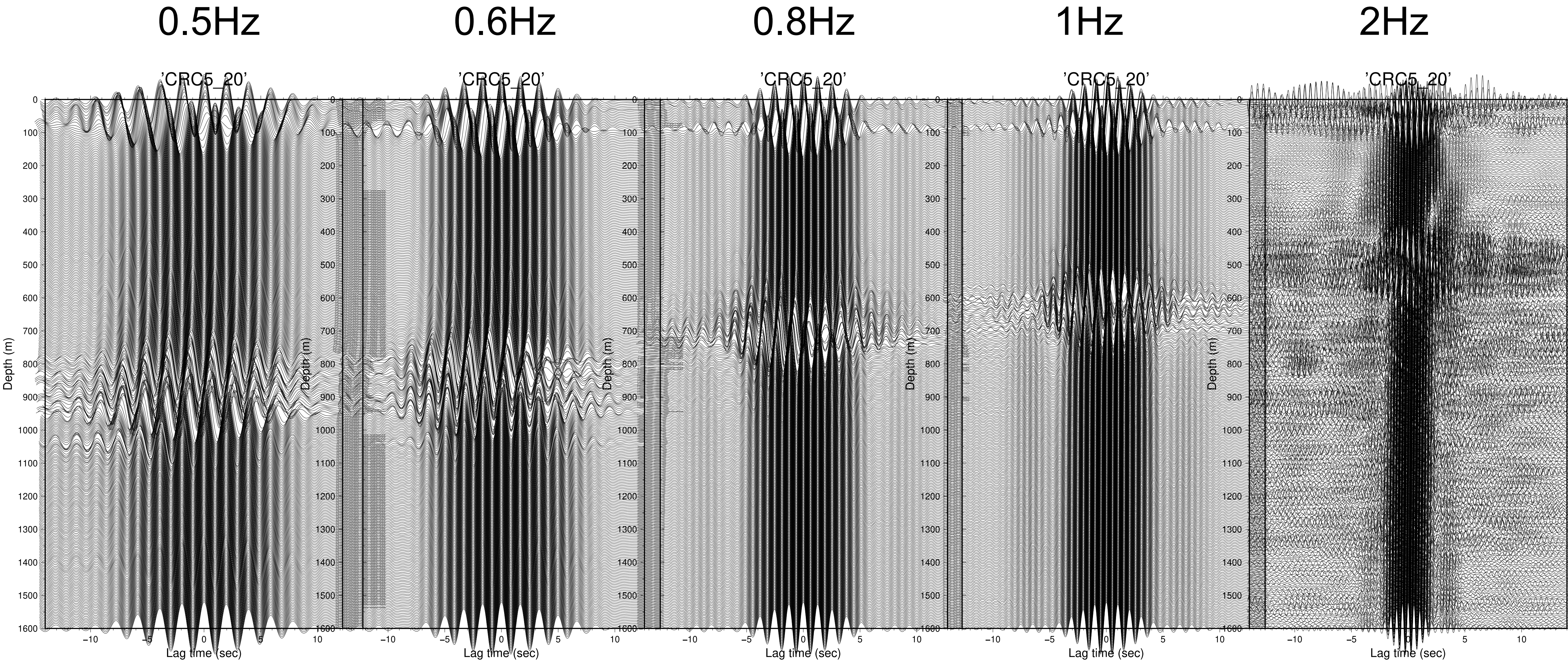

Mode1



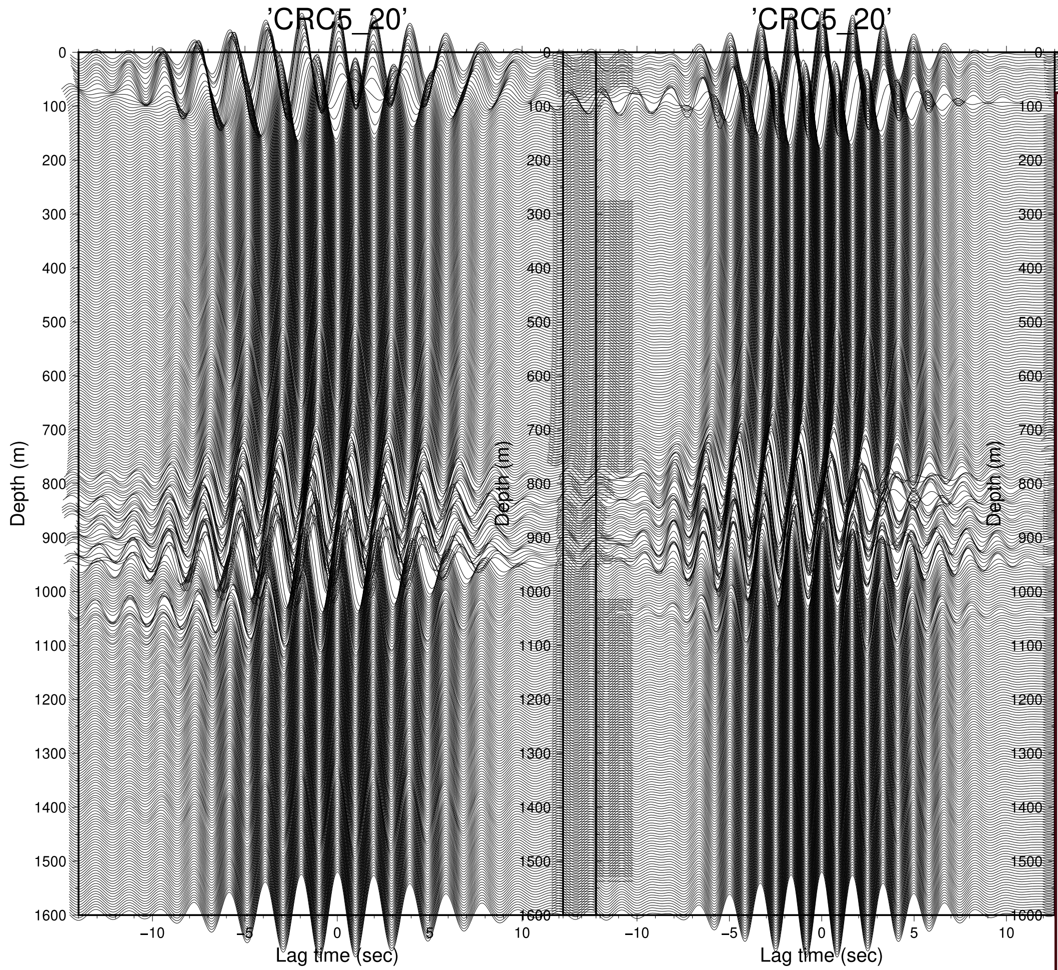



# Polarity flip at shallower depth at higher frequency.

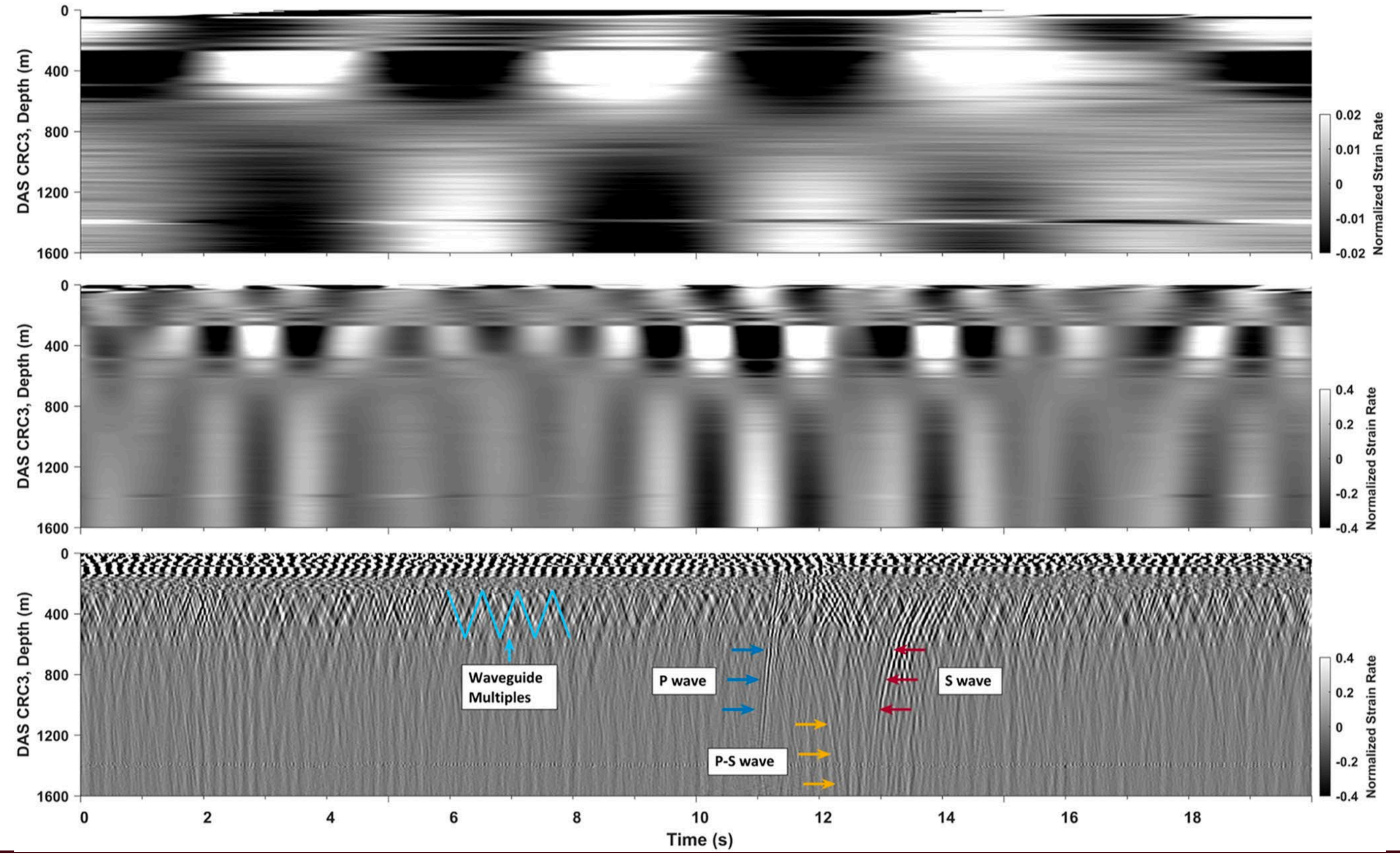


# Polarity flip at shallower depth at higher frequency.

0.5Hz 0.6Hz 0.8Hz 1Hz 2Hz




Similar polarity flip has been found in raw data (Glubokovskikh et al., 2021).



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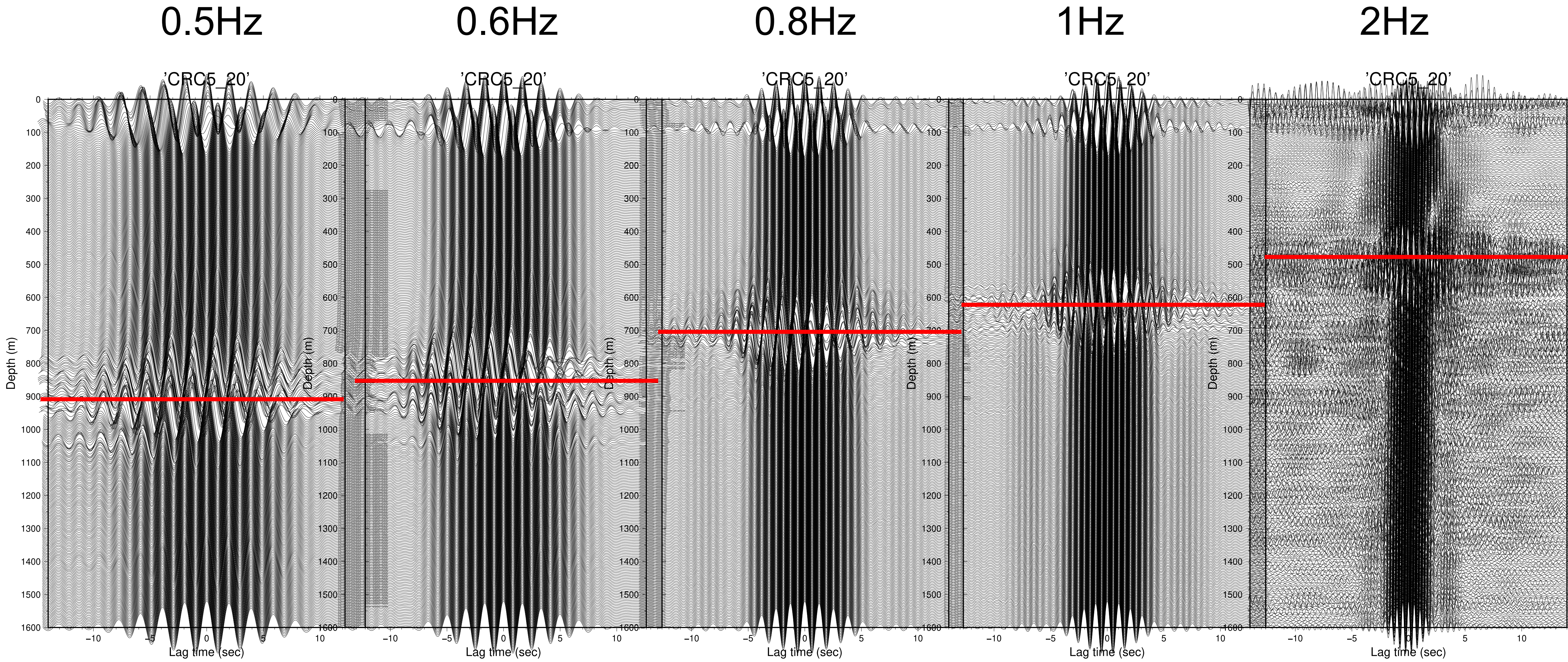
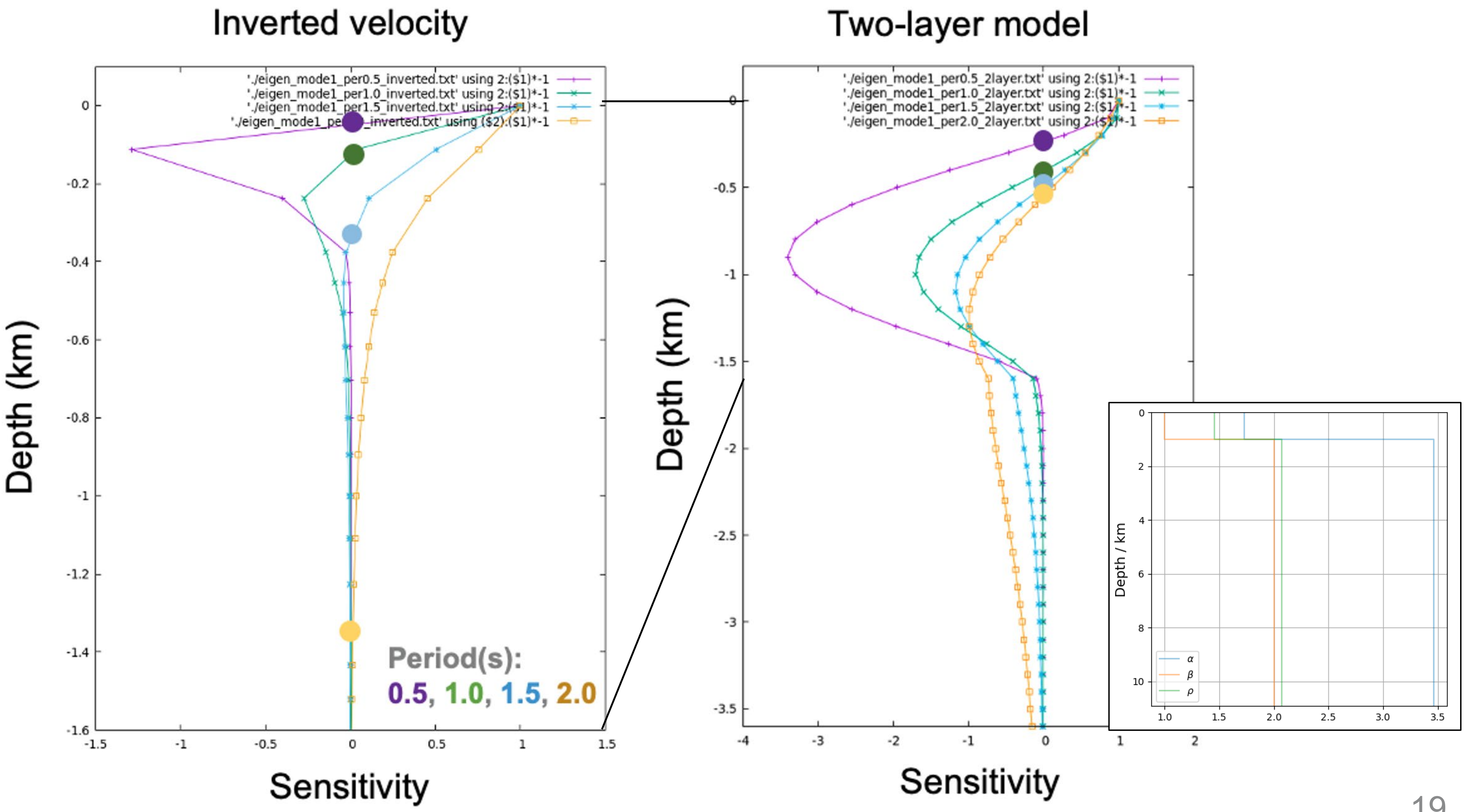


# Theoretical zero-crossing depths fit well with fundamental mode.



# Conclusions

- With ambient noise, we can extract body and surface waves propagating through the injection reservoirs.
- Dispersion and zero-crossing analyses indicate that we mostly extracted the fundamental mode of the Rayleigh wave.
- The inverted velocities match well with well-log data and sensitive to the medium between wells.