

Core Carbon Storage and Monitoring Research (CCSMR): Task 5 – Ambient Seismic Noise Reservoir Imaging for Monitoring

FWP-ESD14095

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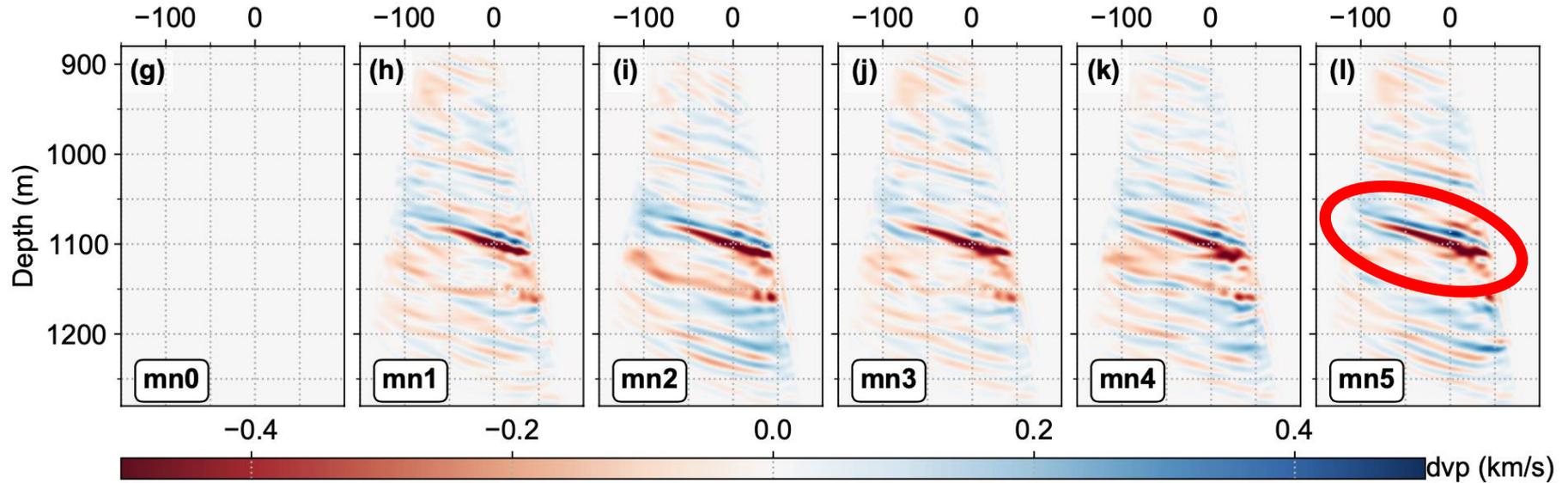


Task overview

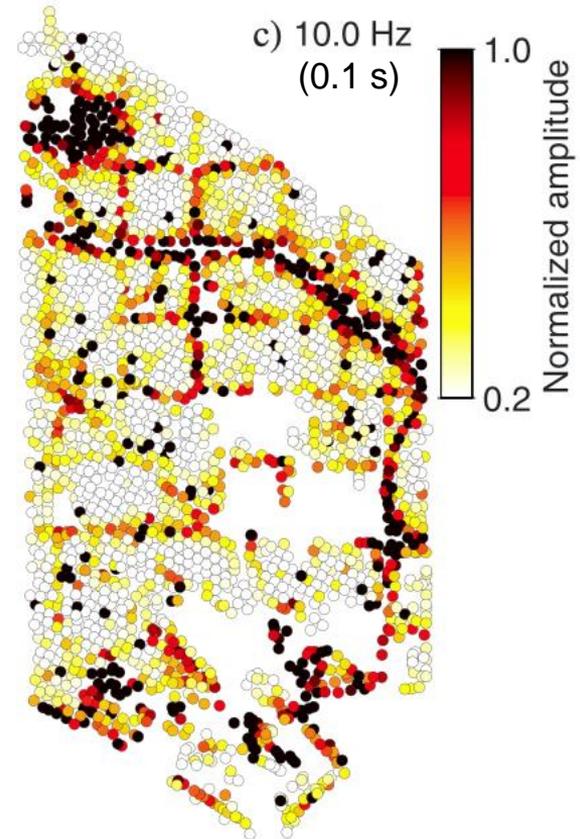
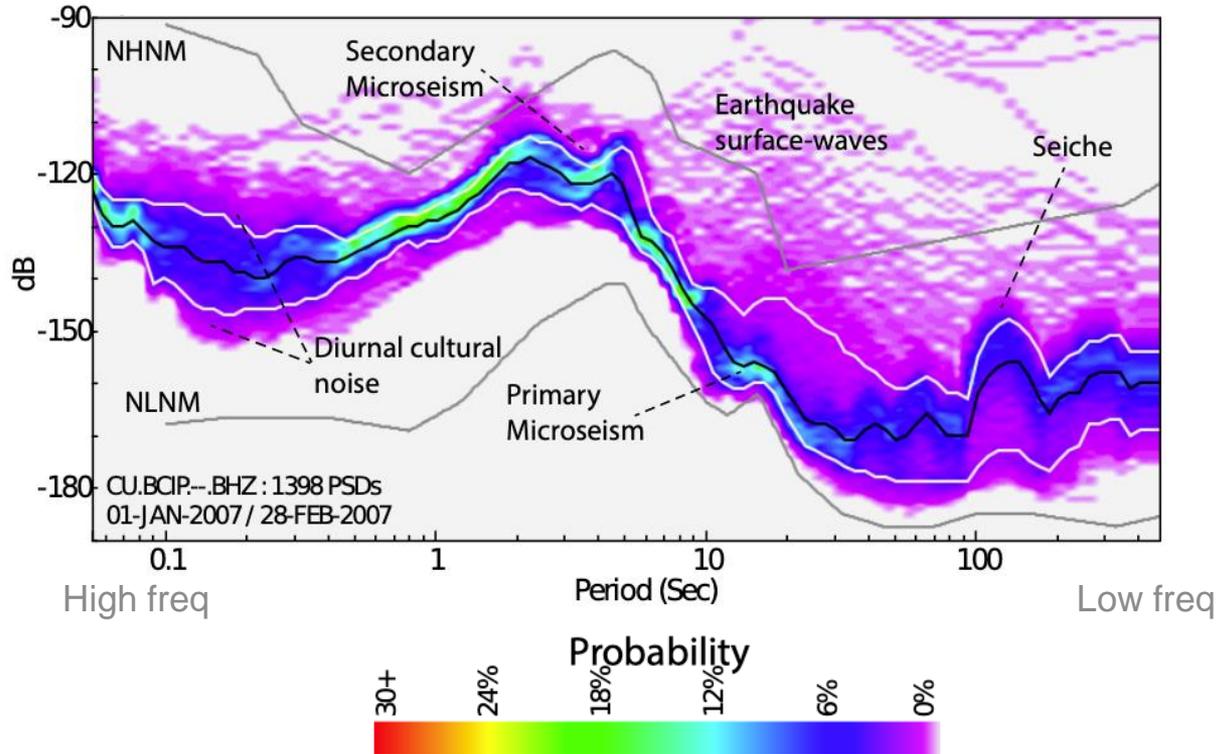
- Task objectives
 - Develop and test ambient-noise imaging approaches for reservoir monitoring to detect CO₂ plume and leakage and characterize the reservoir.
- Task Performance Dates
 - October 1st, 2022 – December 31st, 2023
- Funding
 - DOE: 146K (for Task 5)

Seismic velocities are sensitive to CO₂ distribution.

P-wave velocity changes due to 10,500 tons of CO₂ injected at Nagaoka, Japan, estimated by cross-well active seismic surveys.



What is ambient noise?



Nakata et al., 2015, JGR

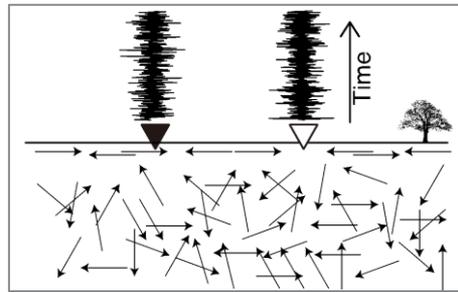
Nakata et al., 2019, CUP

Ambient-noise imaging

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

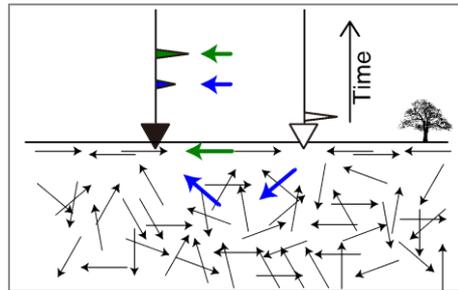
Concept of ambient noise wavefield extraction

High-resolution subsurface imaging with ambient noise

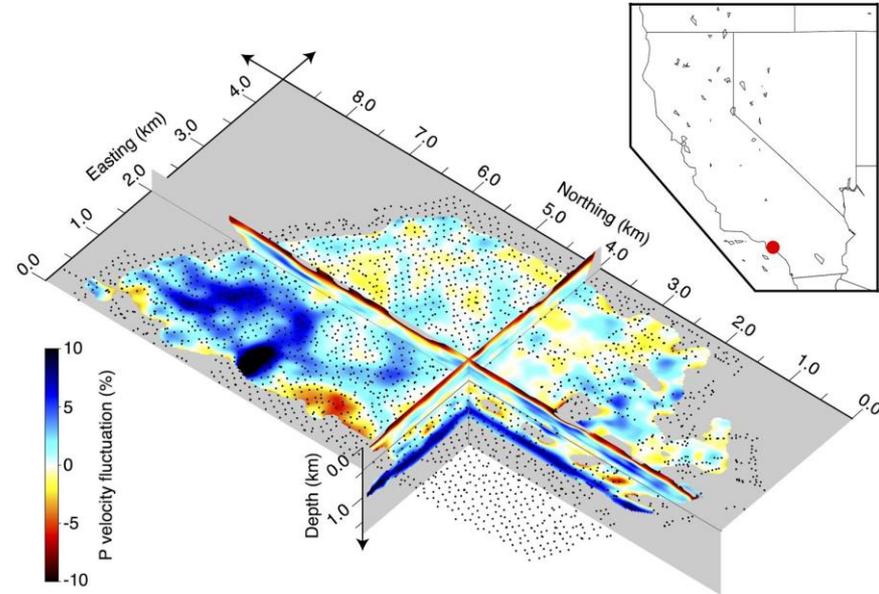


Observed random wavefield

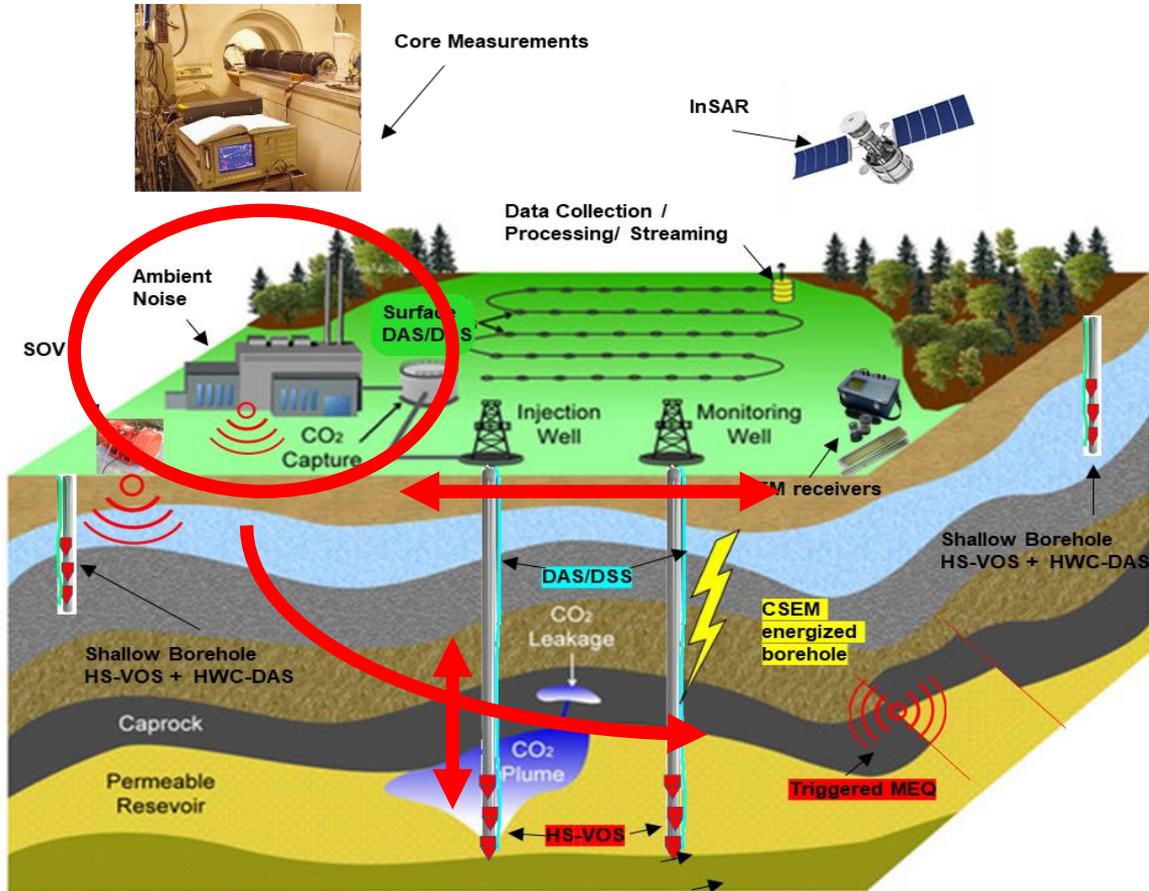
Signal processing



Extracted coherent waves for imaging & monitoring



Motivation



- Reservoir monitoring using single-well and cross-well ambient noise imaging approaches
- Integrate with other geophysical approaches such as active-source, microseismic and EM monitoring in RAPS.

Technical approach

- Goal

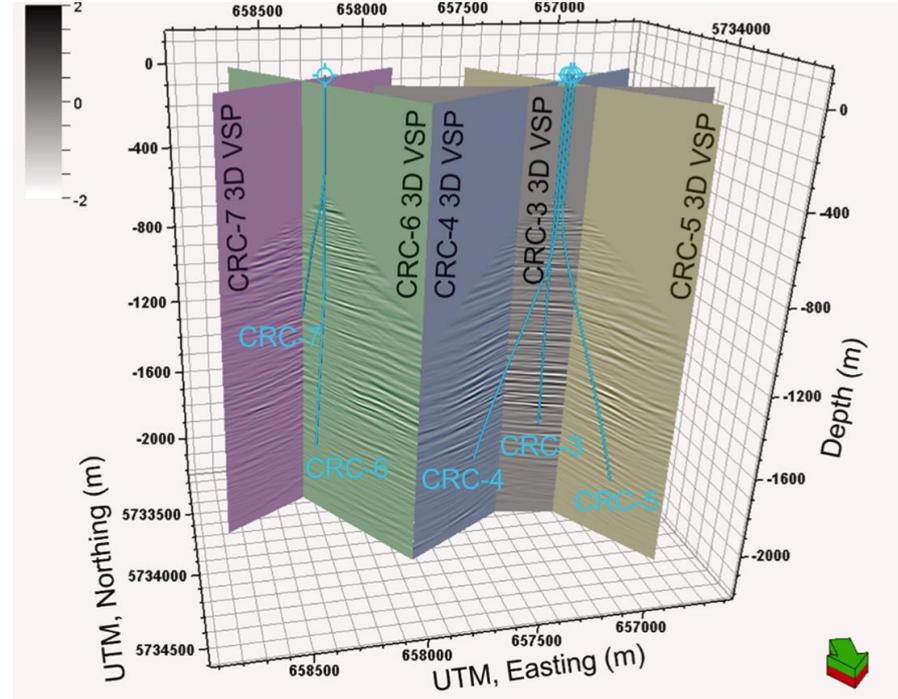
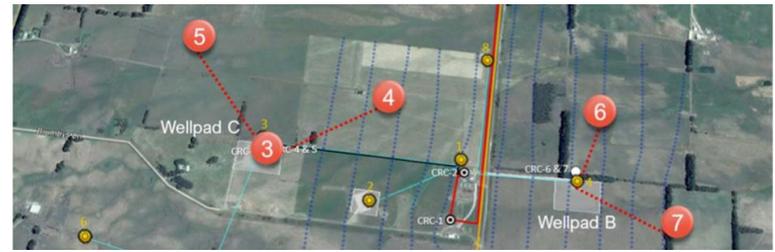
- Develop and test ambient-noise imaging approaches for reservoir monitoring to detect CO₂ plume and leakage and characterize the reservoir.

- Milestones

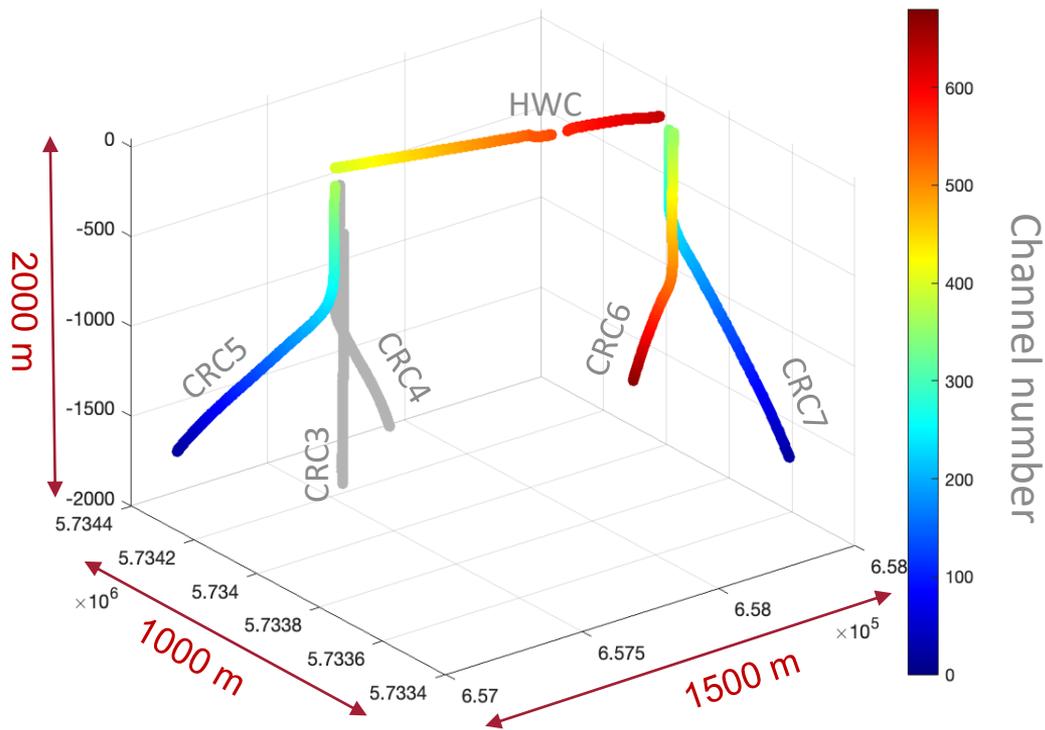
- FY23 Q1: Synthetic test for sensitivity analysis
- FY23 Q2: Preparation of field data & preprocessing
- FY23 Q3: Applying ambient-noise correlation with the field data.
- FY23 Q4: Identification of extracted waves from ambient noise
- FY24 Q1: Applying time-lapse analysis of cross-well tomograms and wavefields for reservoir monitoring

Field dataset

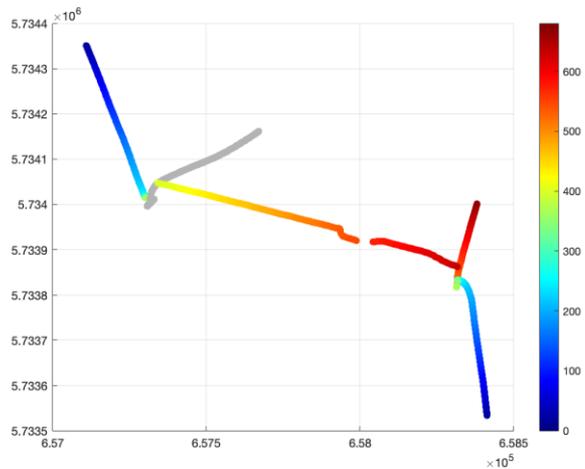
- Otway Test Site in Australia
 - Multiple fiber-instrumented wells
 - Continuous recording of acoustic motion (DAS)
 - One-day data is processed (baseline data).
 - Data recorded in CRC5, CRC6, CRC7 and surface.
 - 250GB/day.
 - 5-m receiver spacing
 - 10-m gauge length



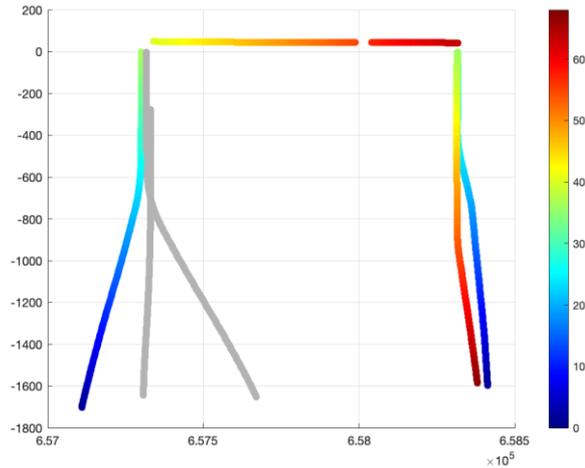
DAS cable trajectory



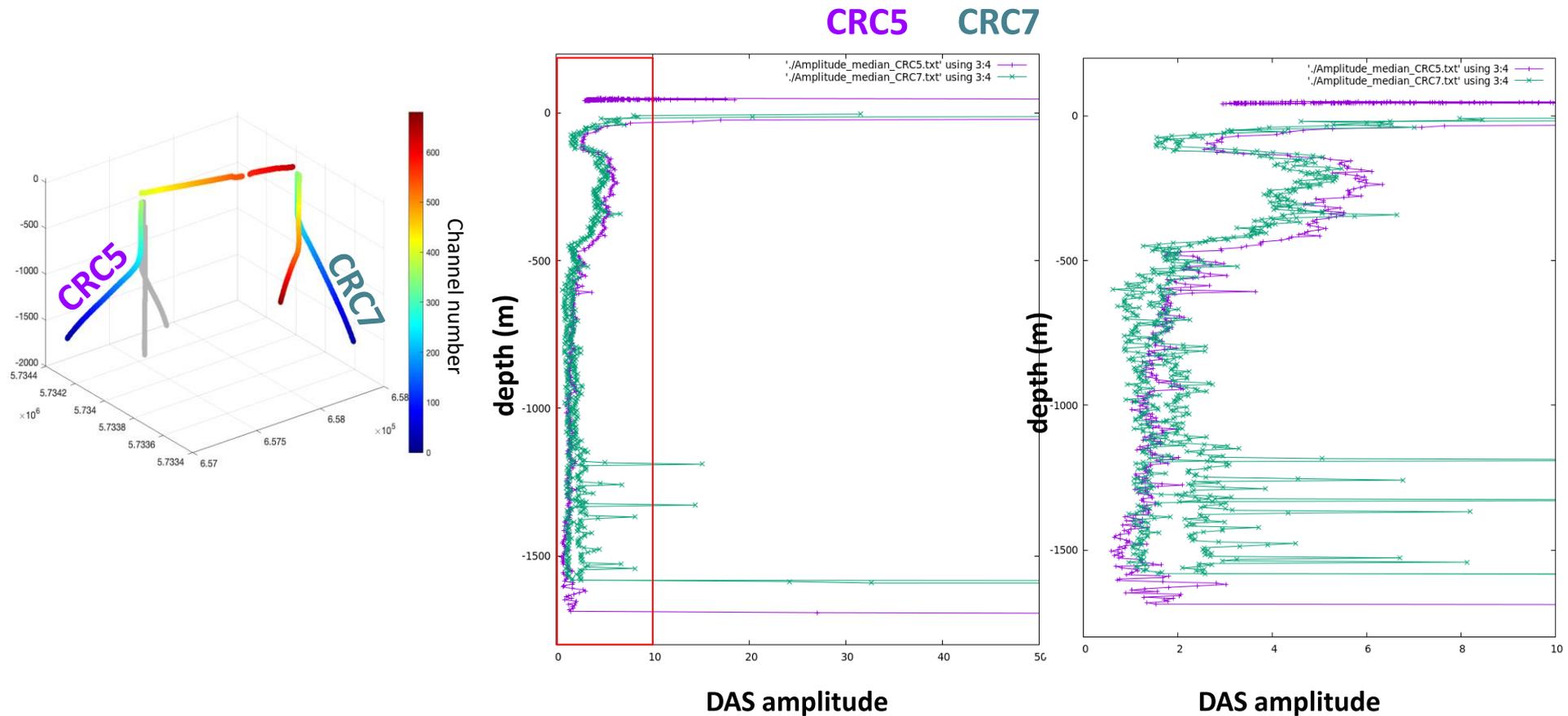
X-Y view

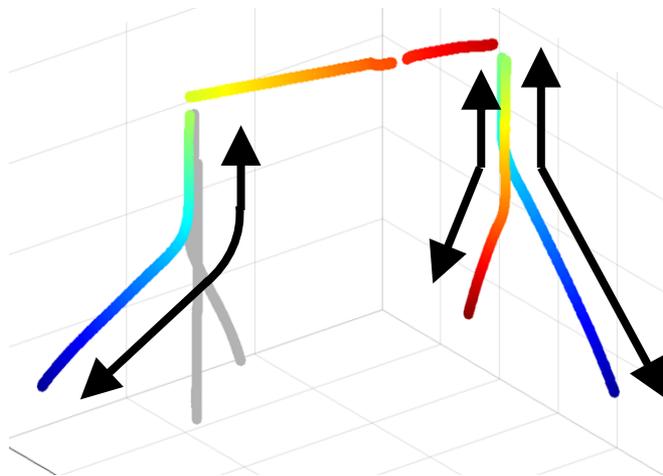


X-Z view



Noise level reduction along the depth

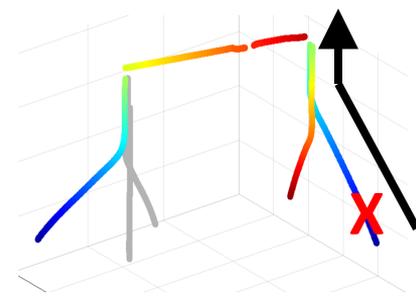
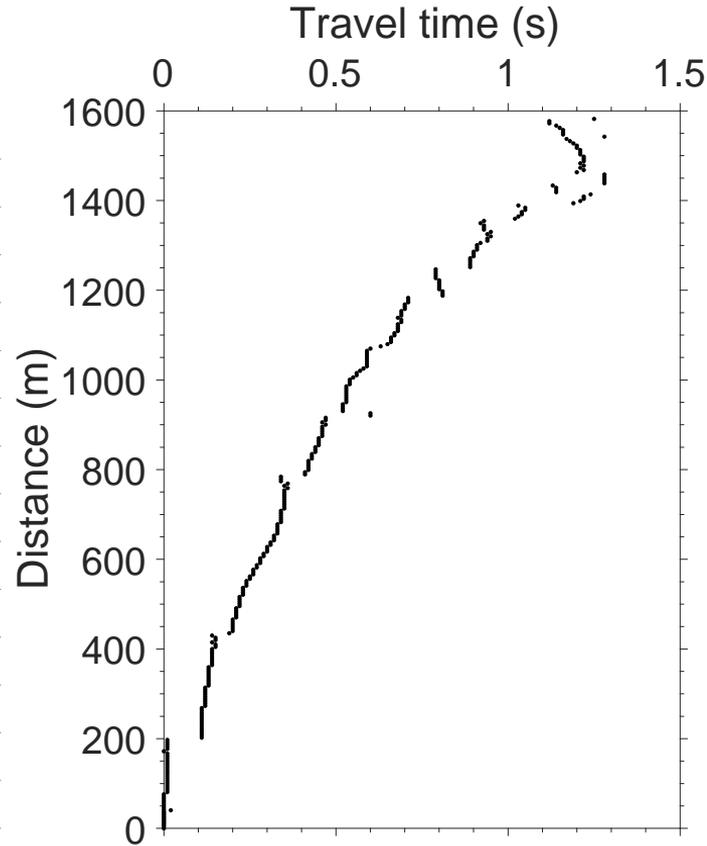
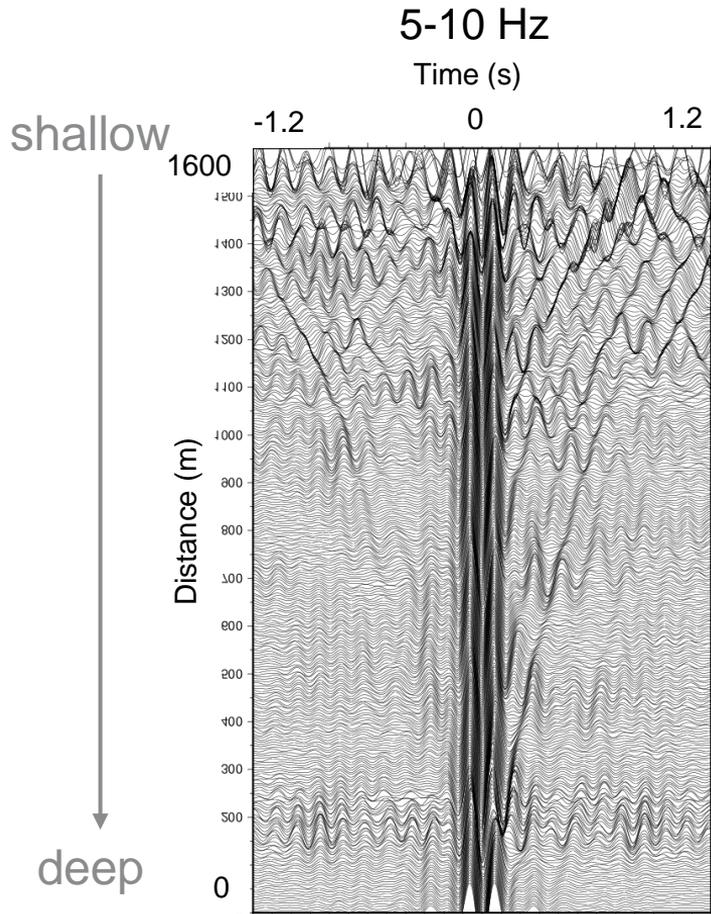




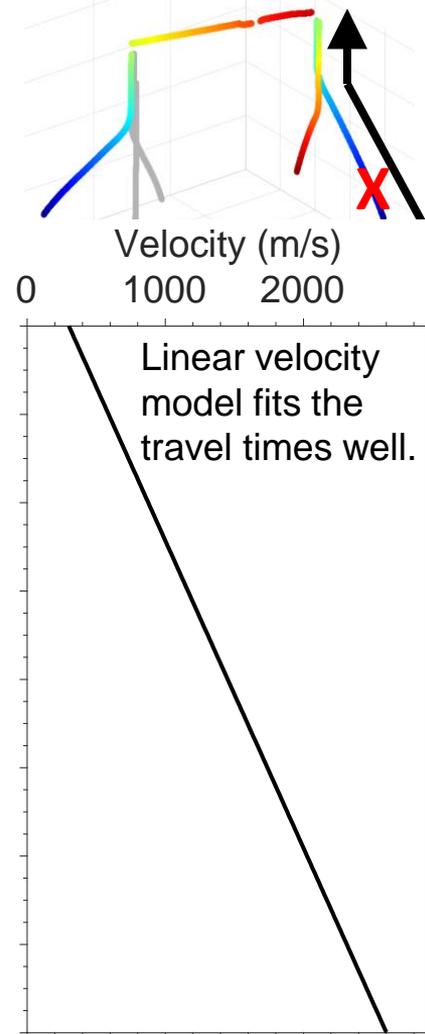
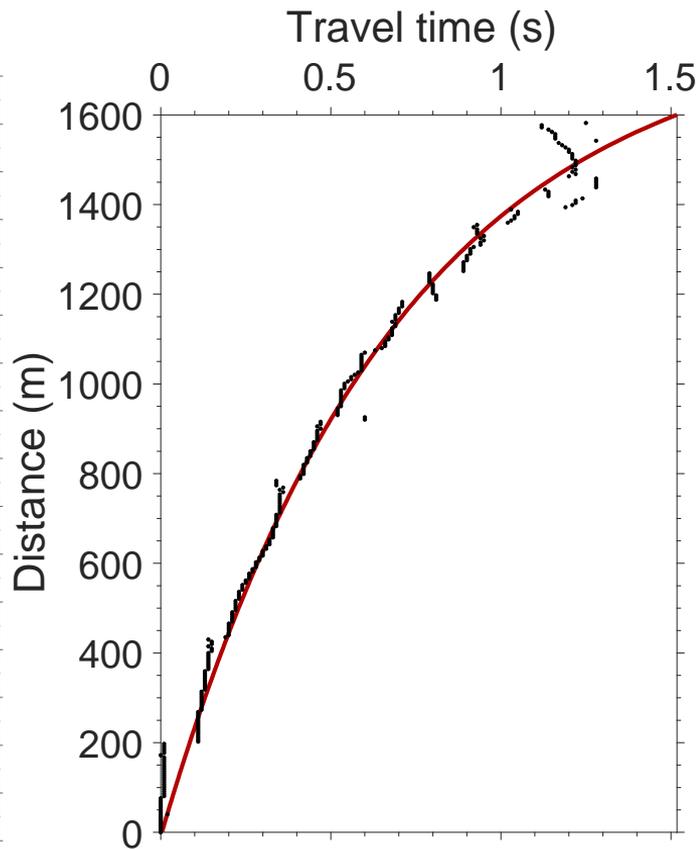
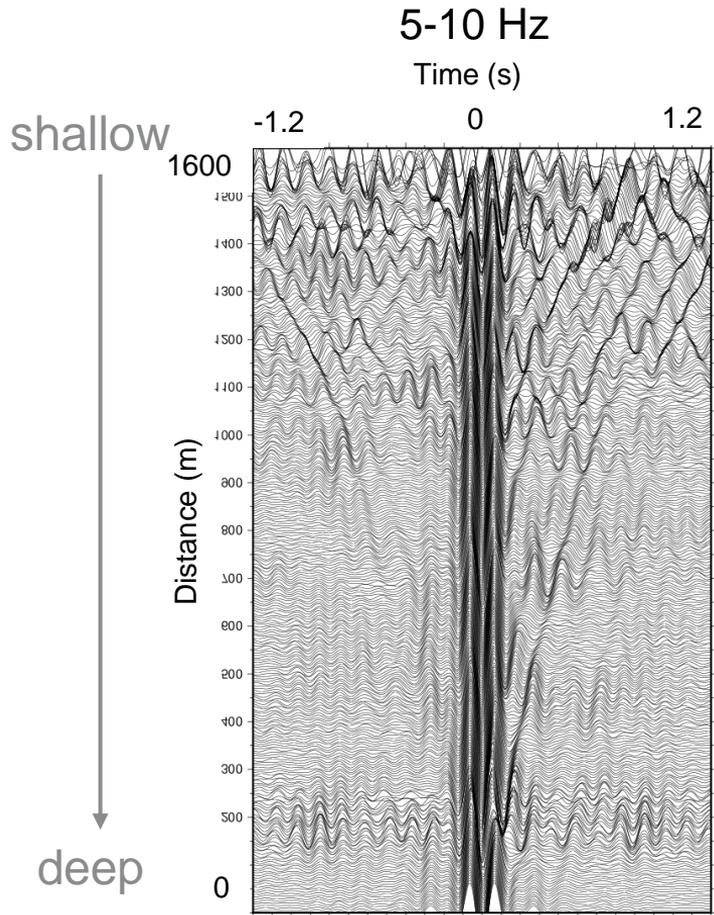
Single-borehole analysis

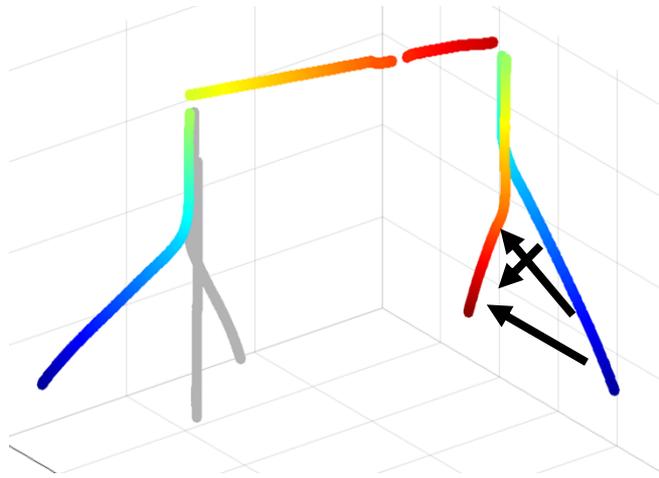
Monitoring along the borehole

CRC7: body wave propagation



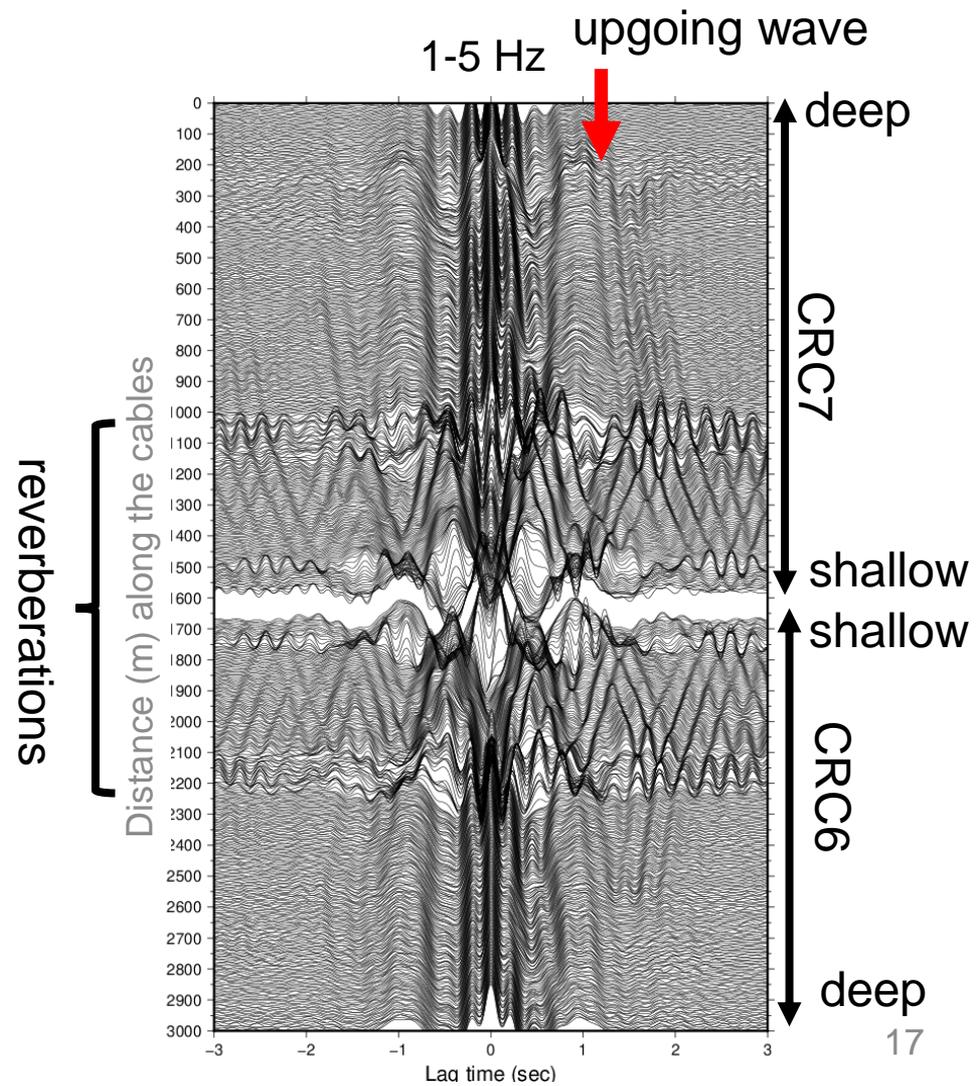
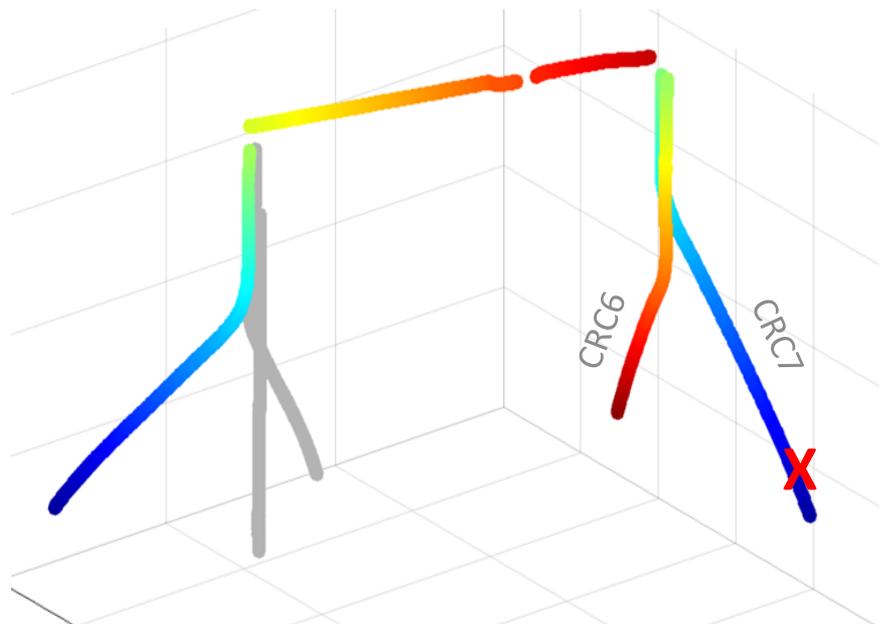
CRC7: body wave propagation



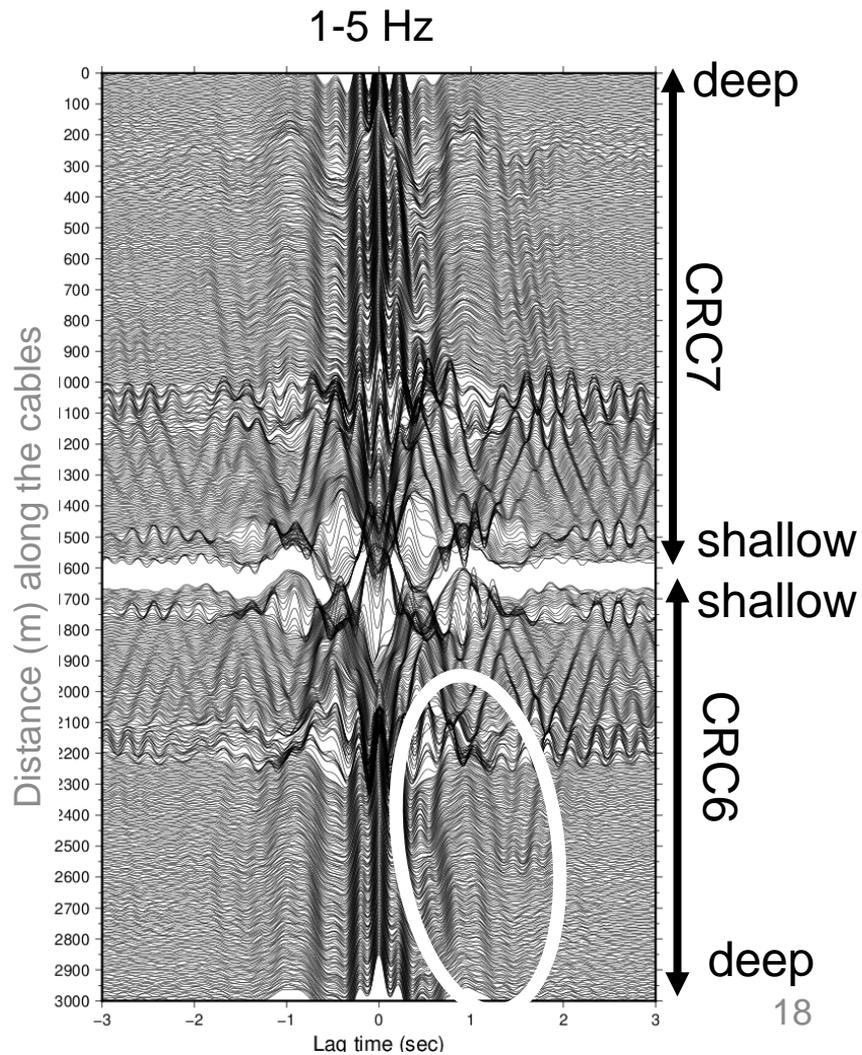
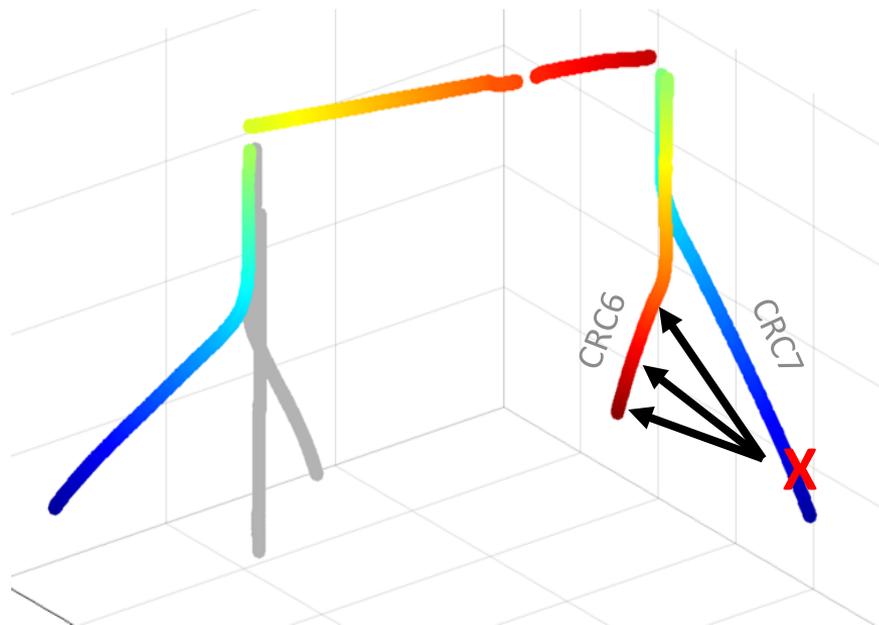


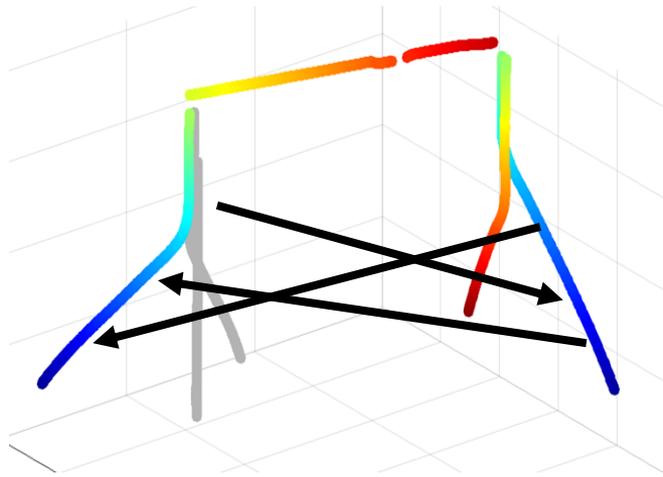
Short-distance cross-borehole analysis

Upgoing reflected (?) waves, reverberations



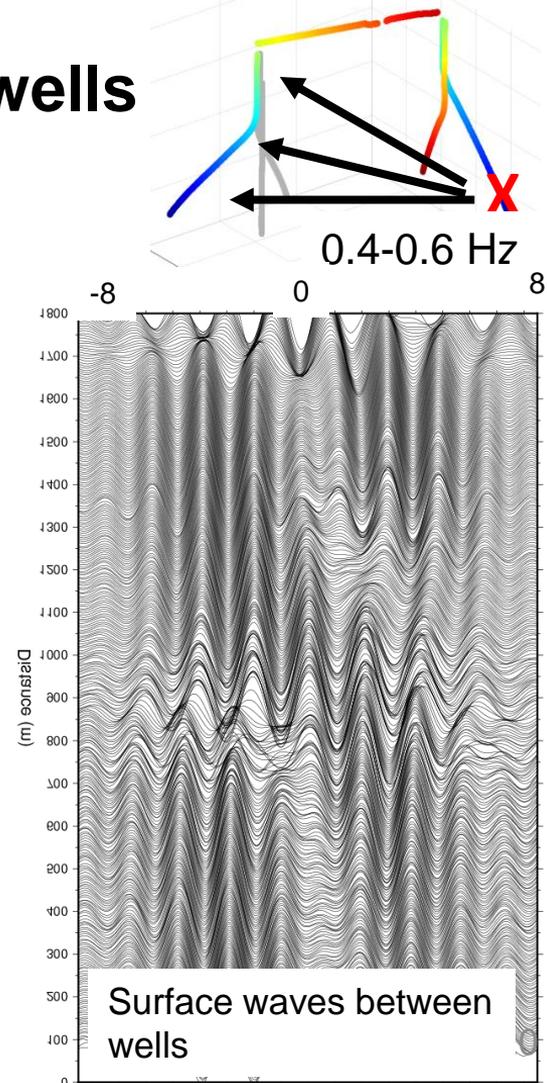
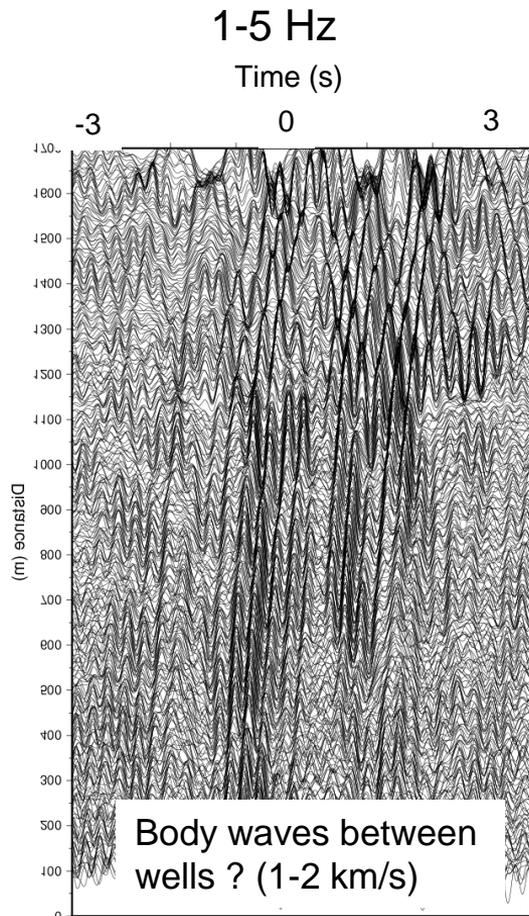
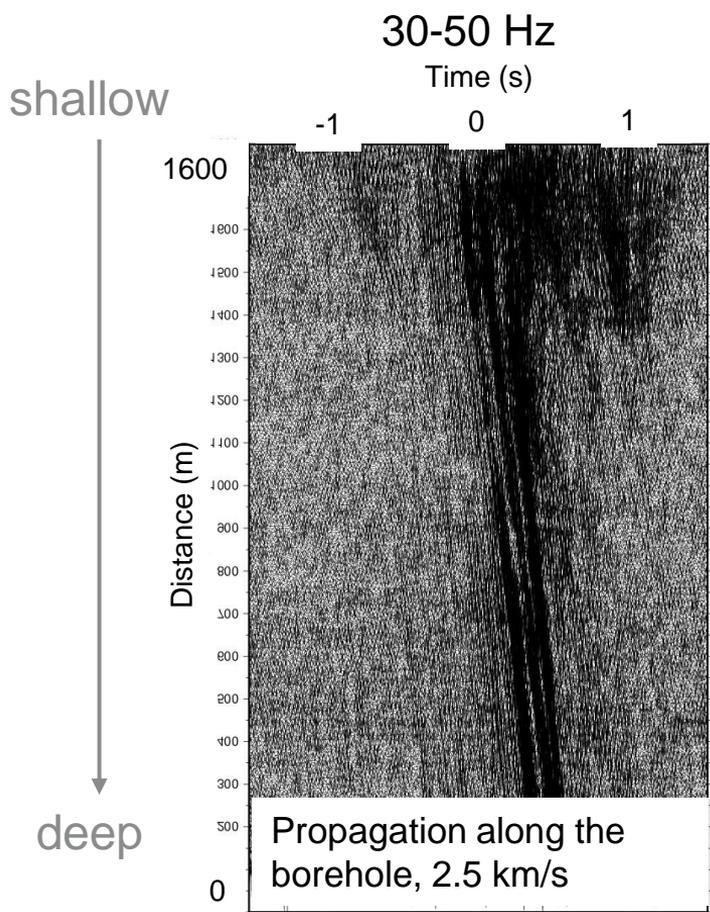
Body-wave propagation between wells





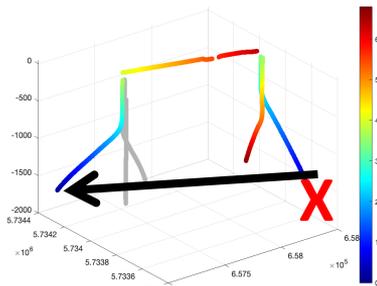
Long-distance cross-borehole analysis

CRC7-CRC5: wave propagation between wells



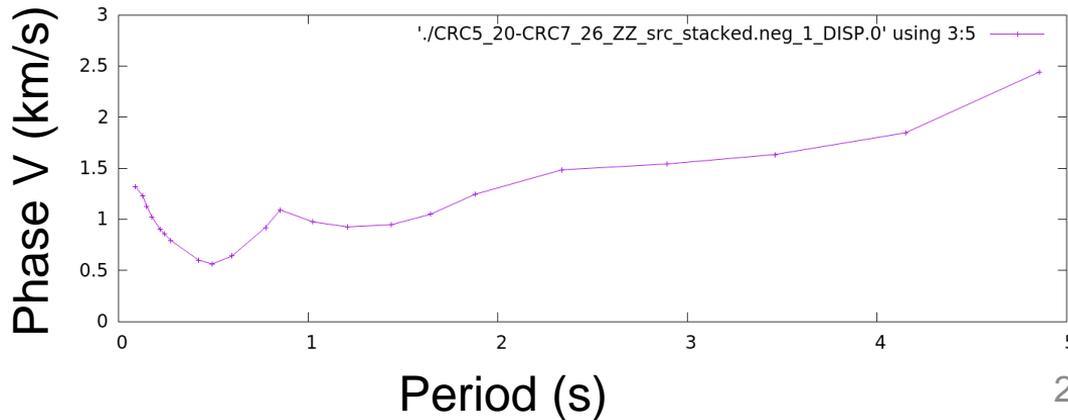
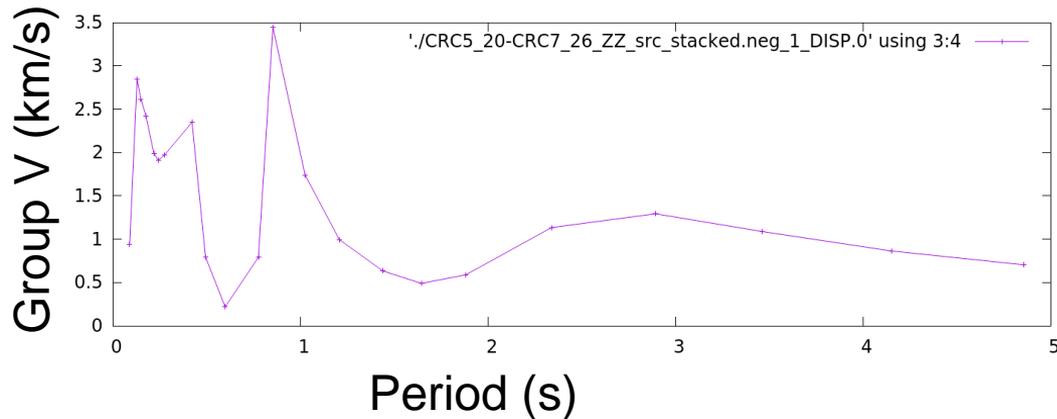
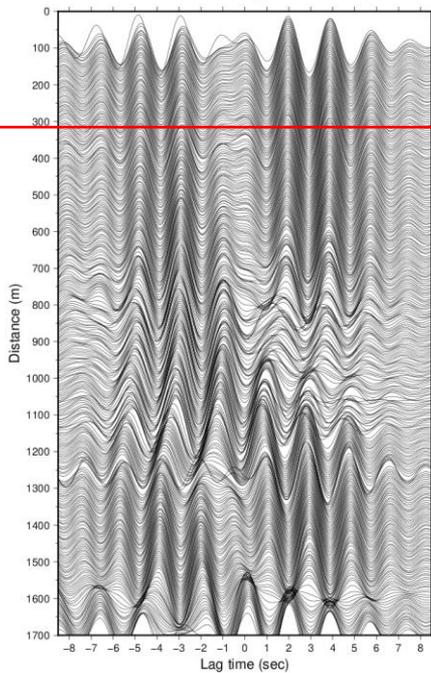
CRC7-CRC5: Surface-wave dispersion analysis

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



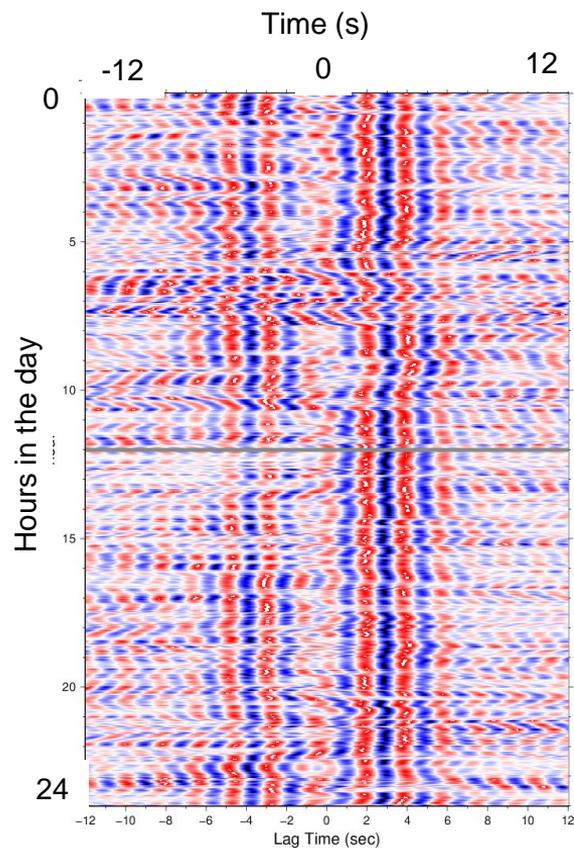
0.4-0.6Hz

'CRC5_20'

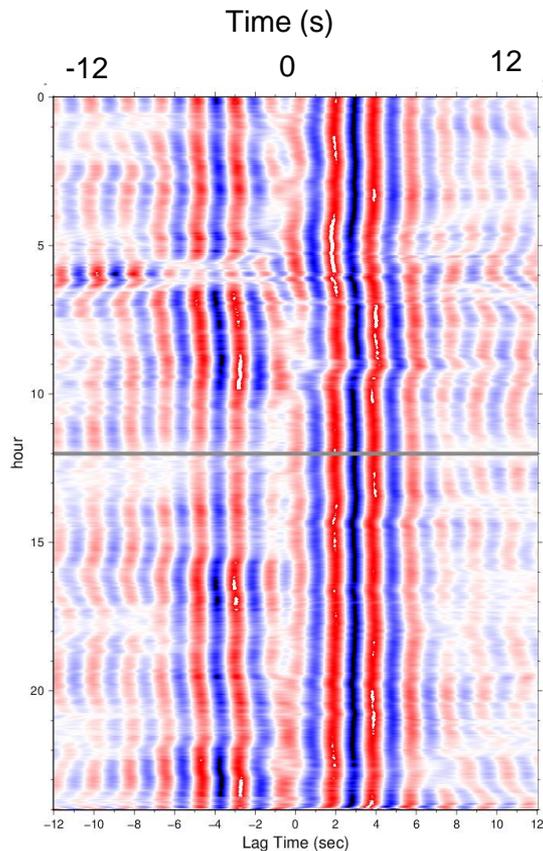


CRC7-CRC5: Repeatability of signals

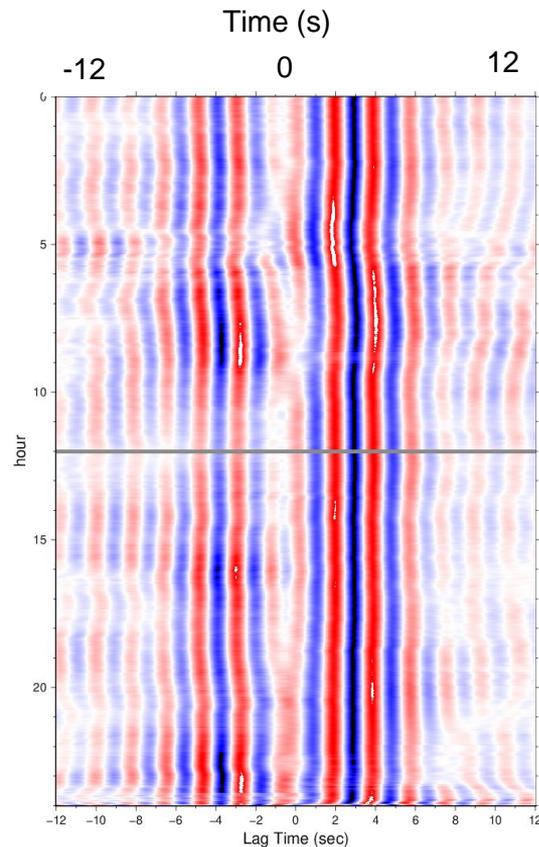
10 min window



60 min window



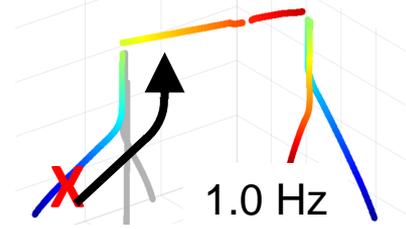
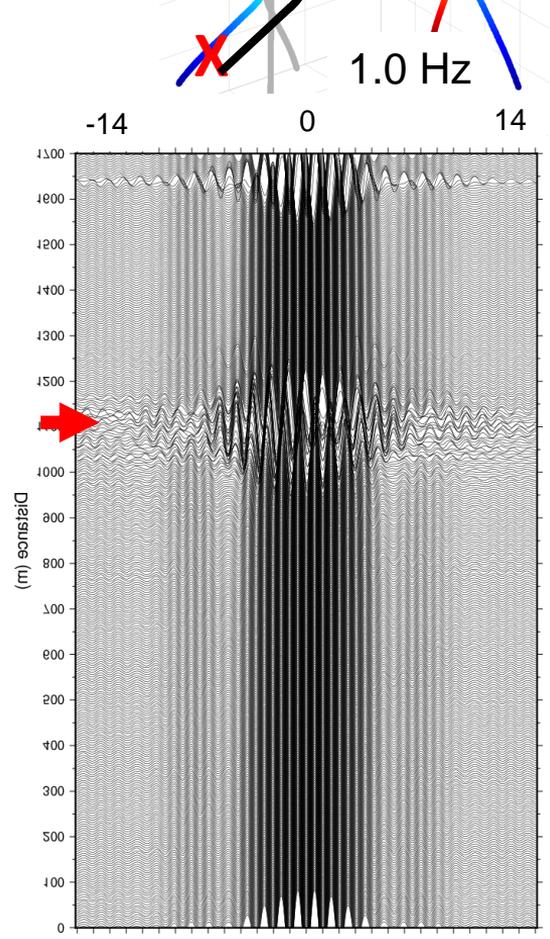
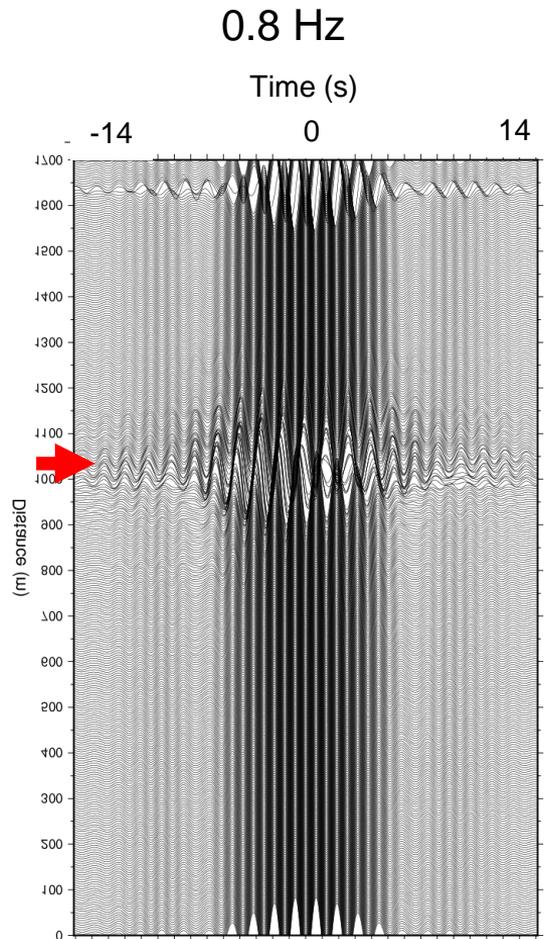
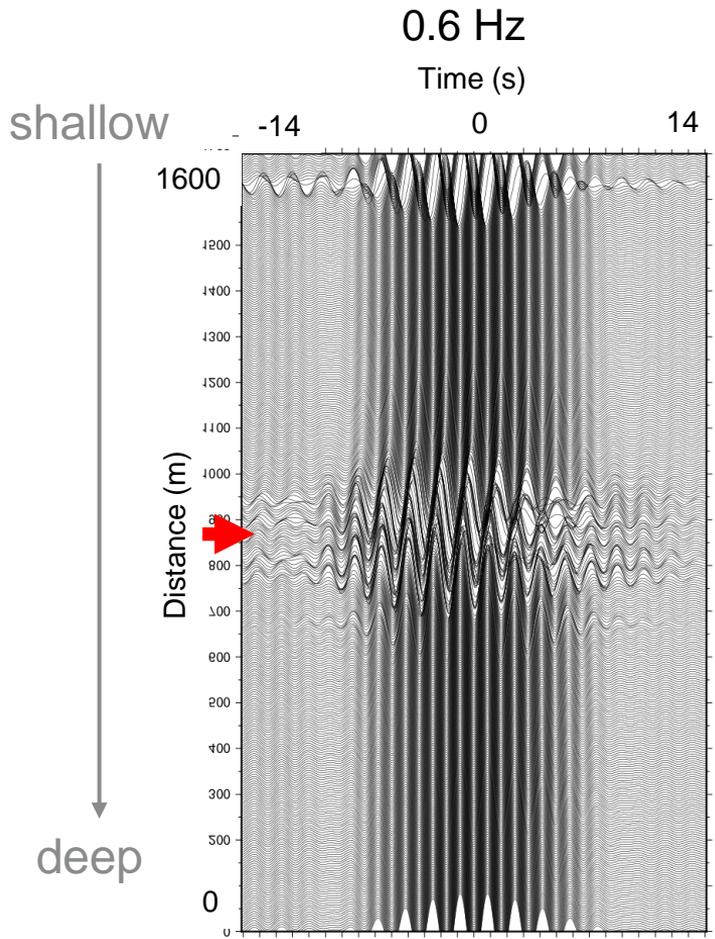
120 min window



Next steps

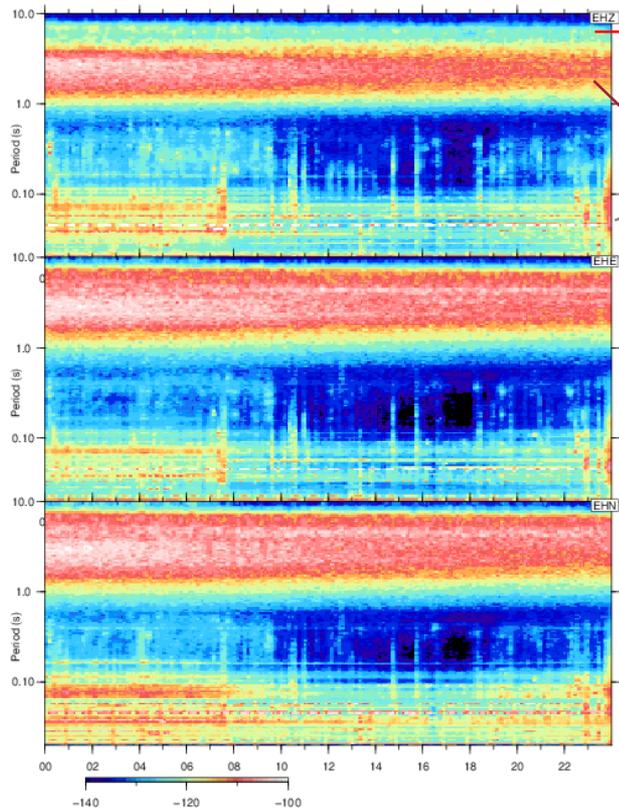
- Continue working on wave identification
- Velocity estimation with the extracted waves
- Improvement of signal-to-noise ratio with pre- and post-processing.

CRC5: First-order surface waves at low freq.



AUHPC (nearby broadband station)

Station AUHPC, 10-31-2020

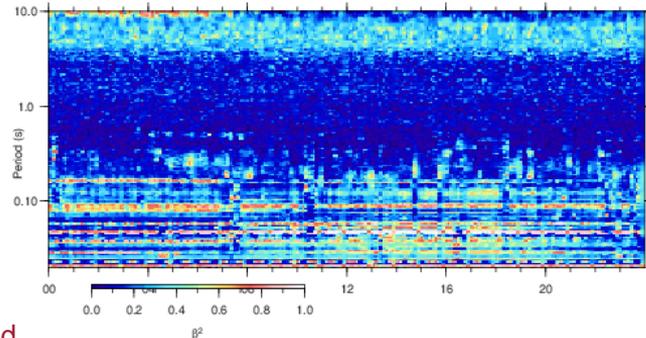


0.15 Hz: microseisms
Weaker but slightly polarized

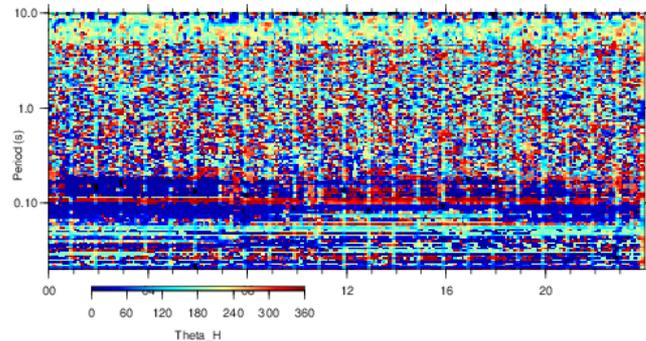
0.3-0.6 Hz: strong but scattered

>10 Hz: strong, polarized and
Only at shallow depth

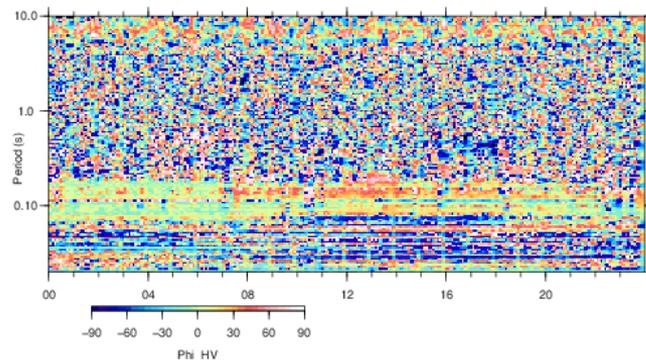
Degree of polarization



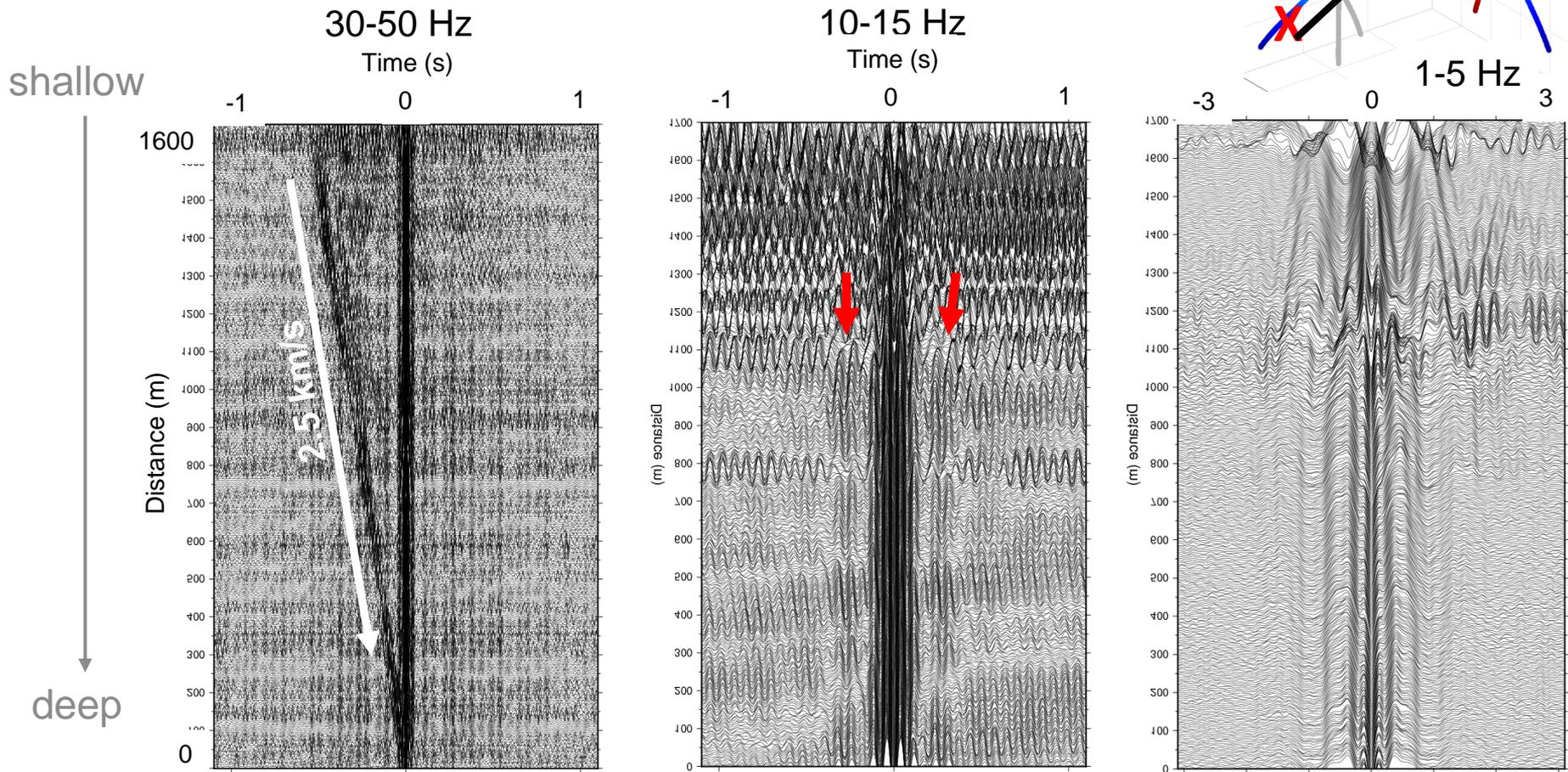
BAZ



Phase shift
Z/H



CRC5: wave propagation at higher frequencies



Similar waves as single-well case

