Ambient noise correlation study at the CaMI Field Research Station

Marie Macquet and Don Lawton

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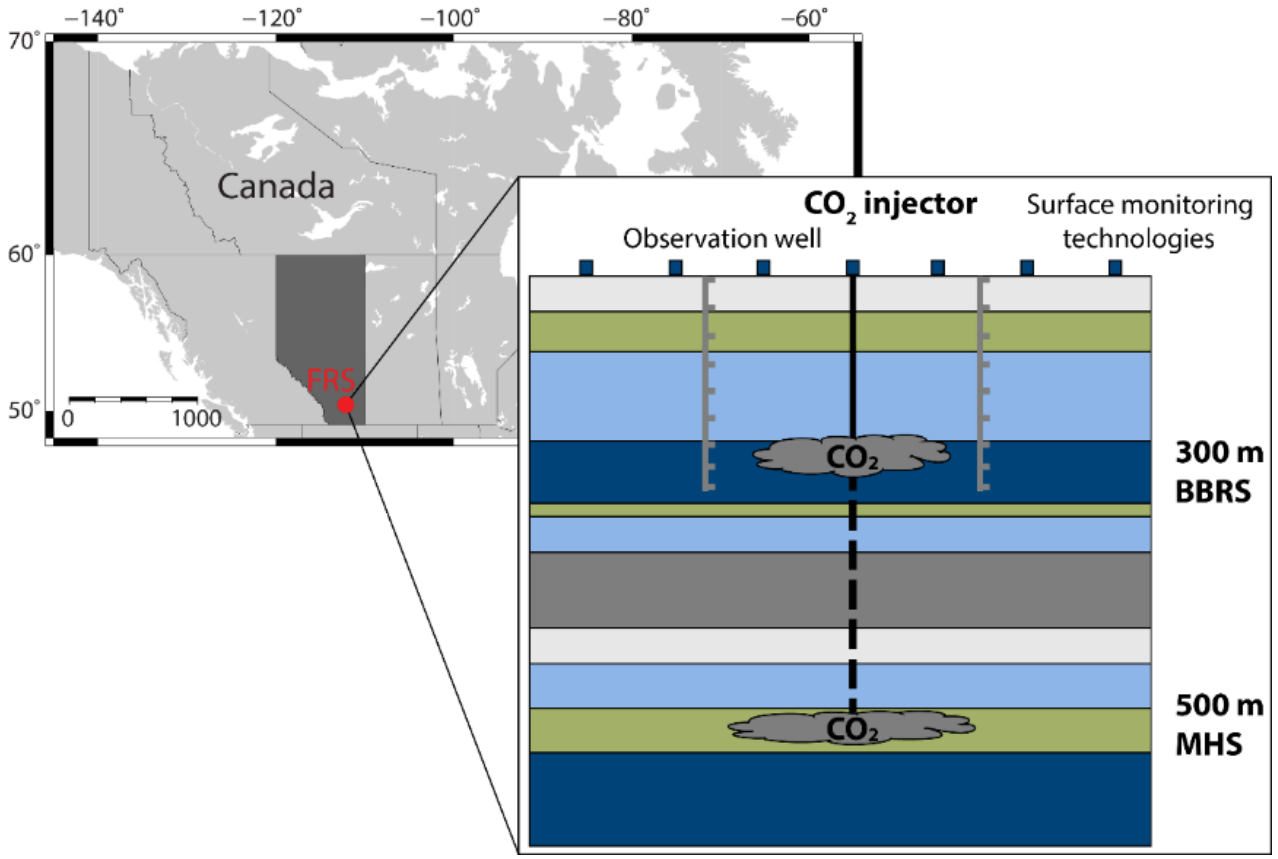
NSERC CRSNG
UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
Department of Geoscience
CMC Containment & Monitoring Institute

Field Research Station

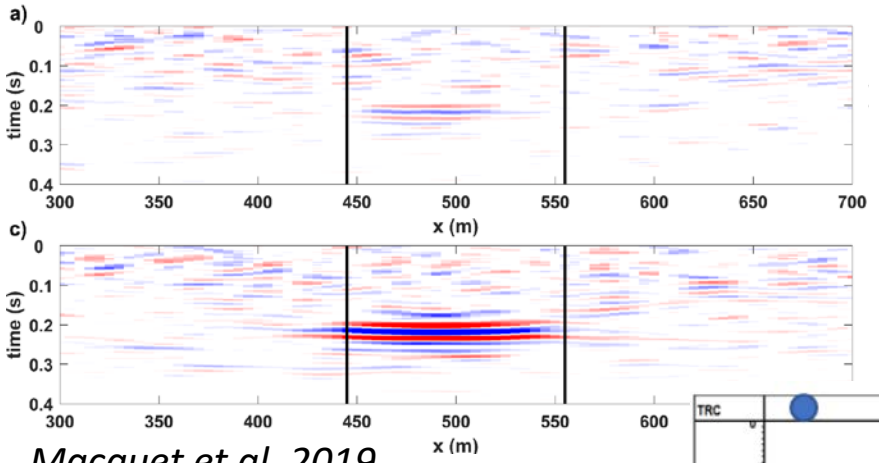
⇒ **Injection of a small amount of CO_2 (<400/tons per year) at shallow depth (300m) to simulate a leakage**



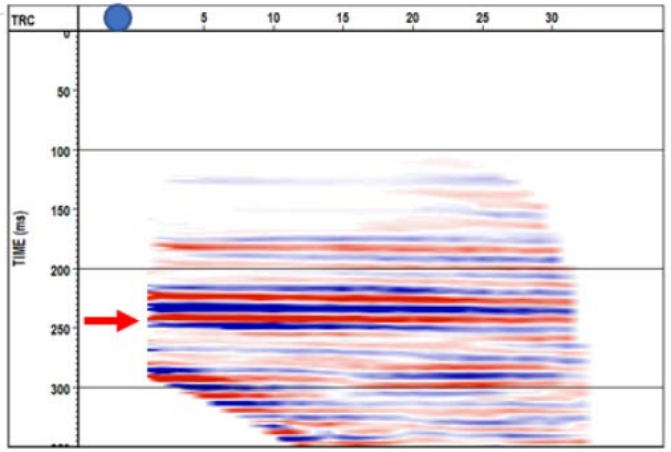
Developed by CMC Research Institutes Inc and University of Calgary

- A site for development and demonstration of MMV technologies for carbon capture and storage (CCS) as well as general containment and conformance monitoring for other applications.
- Undertake controlled CO_2 release at 300 m (Phase 1) & 500 m (Phase 2) depth; up to 400 t/yr.
- Determine CO_2 detection thresholds at shallow to intermediate depths.
- Develop and assess technologies for continuous reservoir, cap rock, overburden, and groundwater monitoring.
- University & industry field training.

Active seismic methods – Pro and con

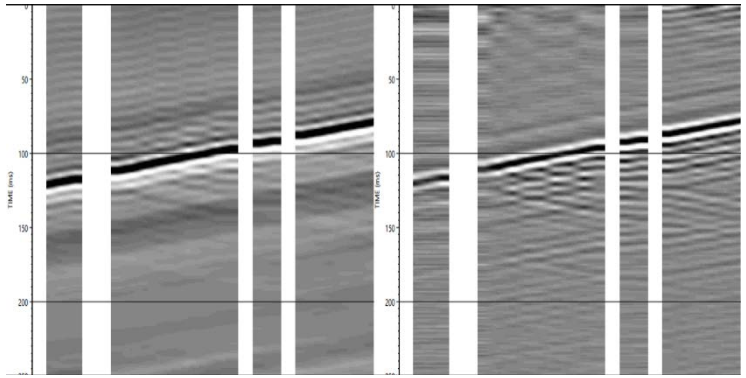


Macquet et al. 2019



Gordon and Lawton 2018

Vibroseis source **GPUSA**



Spackman and Lawton 2018

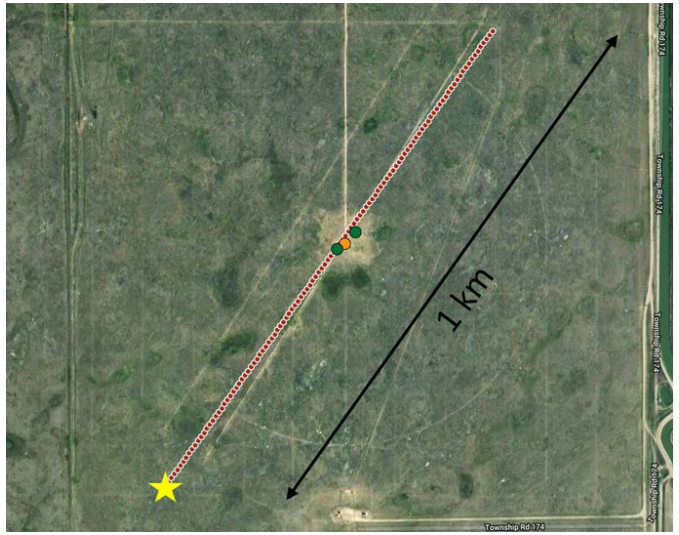
Active seismic surface : Known method but heavy to repeat

VSP DAS : fully vertical coverage but uncertainty on channel depth and low SNR

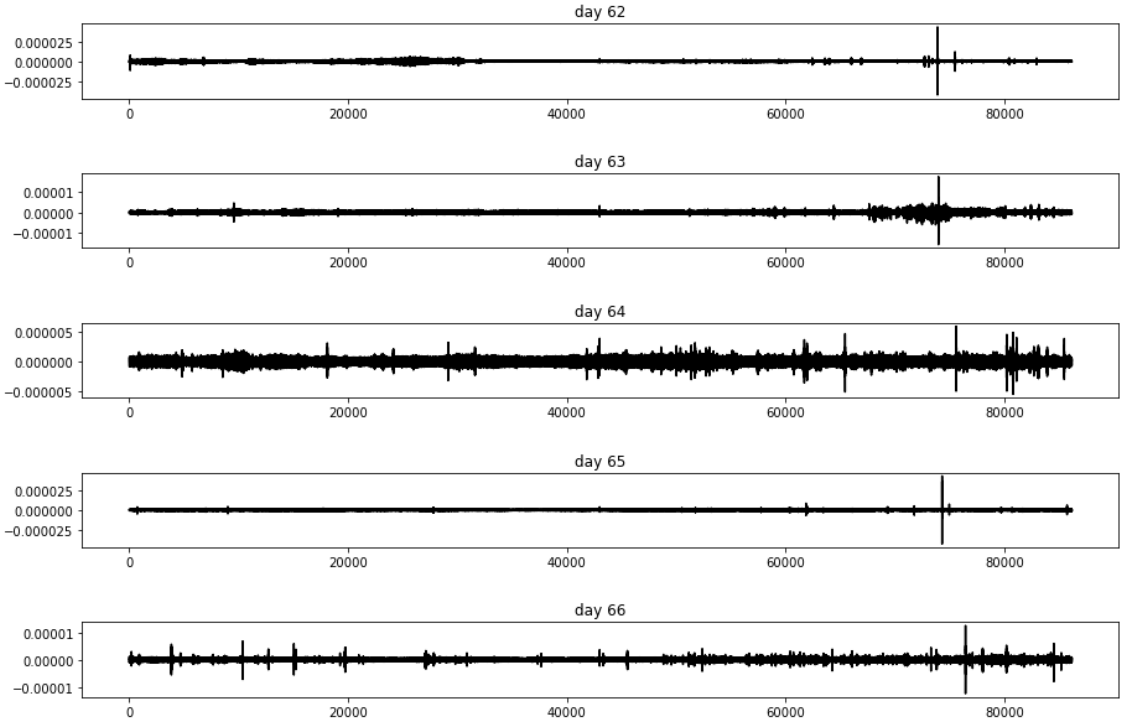
(Semi) continuous seismic source : good repeatability of the measurements but new technology

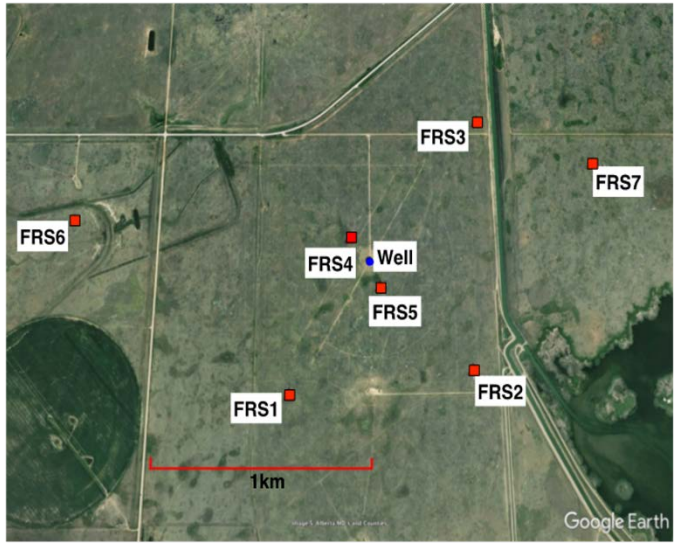
Remain punctual => how to capture transient changes?

Continuous seismic data



Feb. 2018
112 geophones
25 days





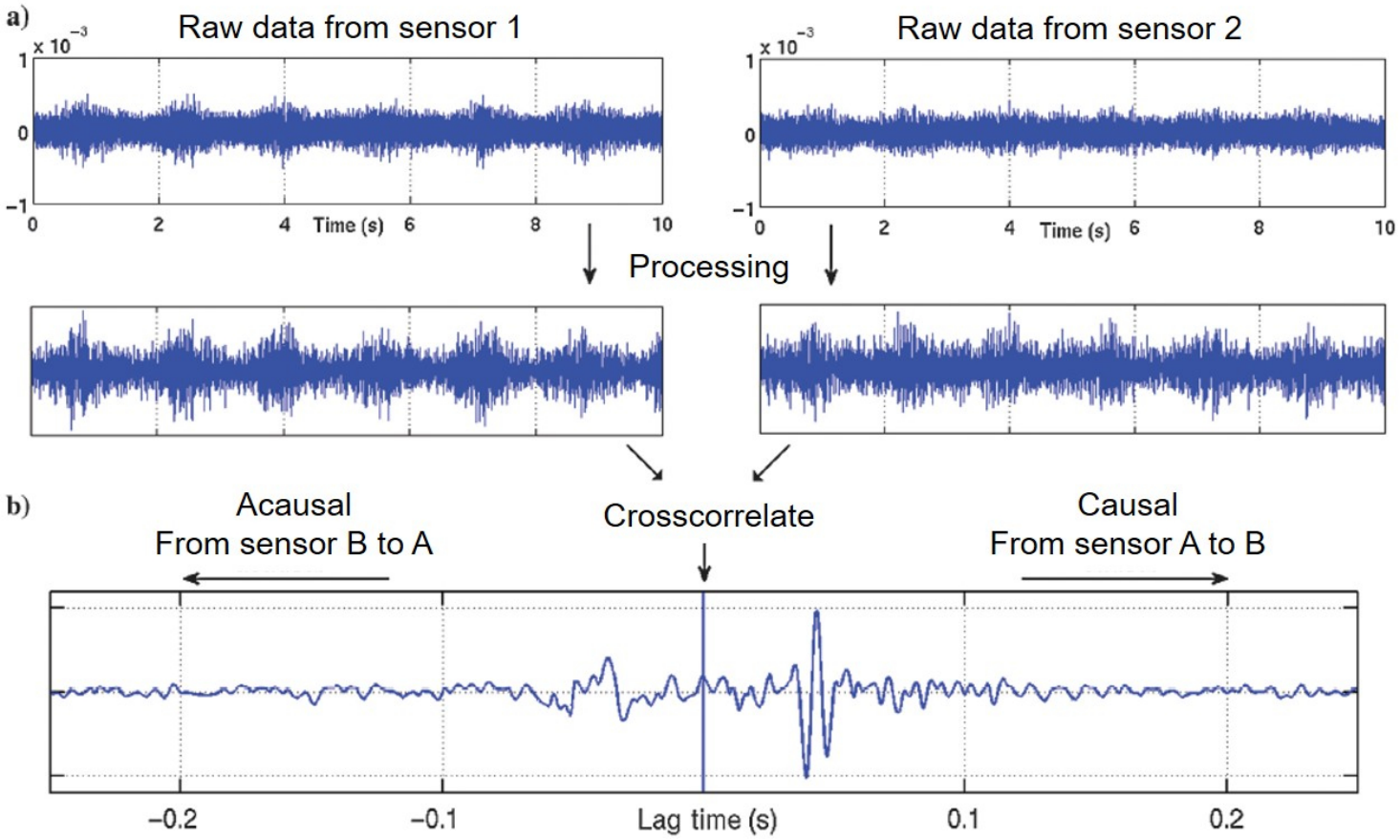
Since October 2015
7 broadband stations

- to study the ***possible microseismicity*** linked to CO_2 injection

- to study the possibility of using the ***ambient noise correlation method*** as a tool for CO_2 injection monitoring

Ambient noise correlation method

Principle *:* reconstruct the Green's function by correlating the continuous ambient noise recorded between two captors.



For tomography

Surface waves

⇒ dispersion curves

⇒ inversion

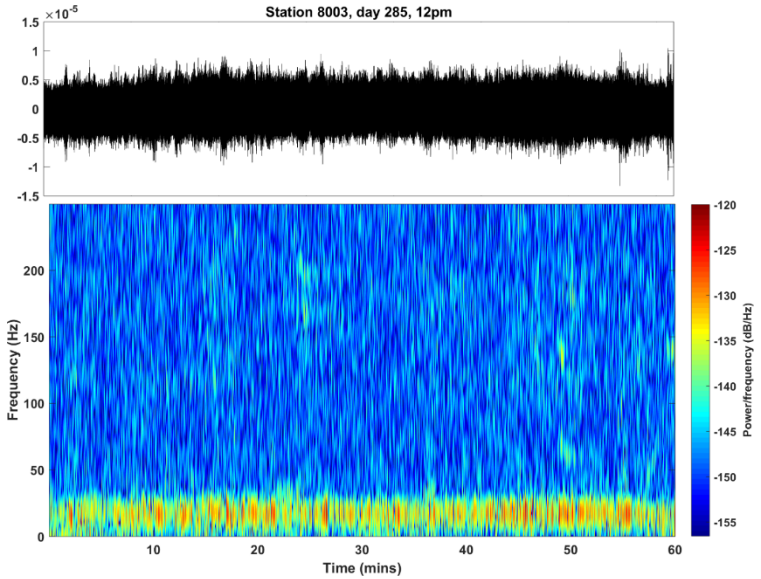
⇒ elastic models

For monitoring

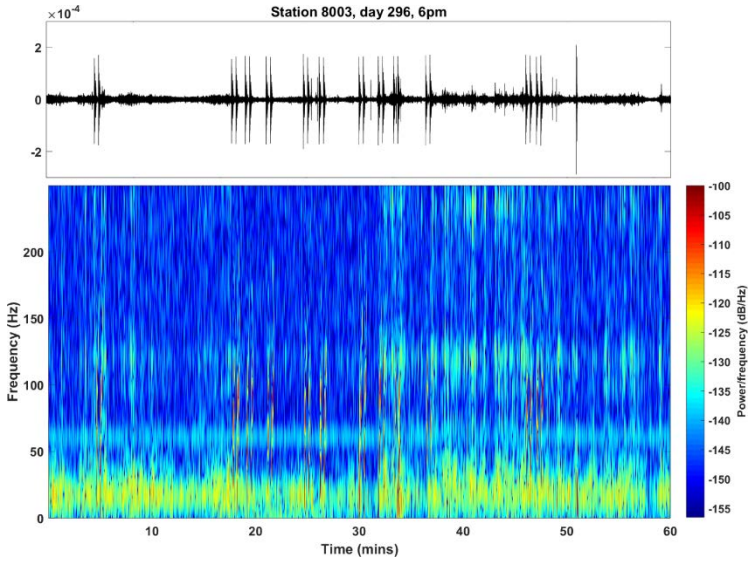
If the medium changes, the result of the Green's function will change

Continuous data

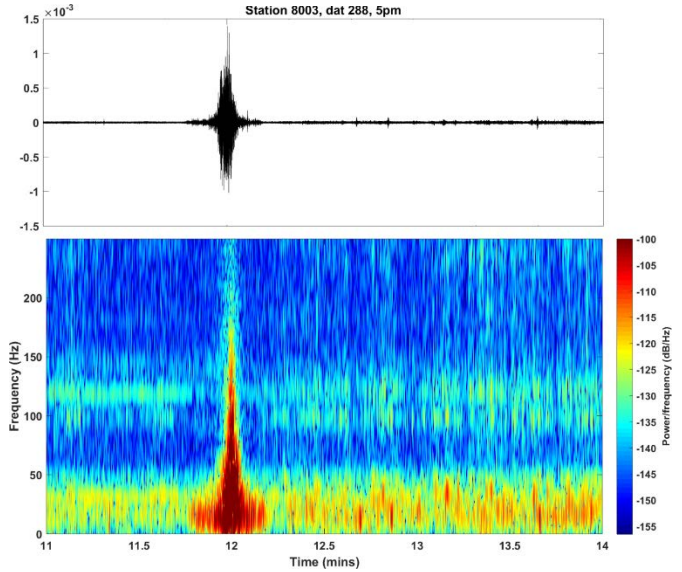
1hour “quiet”



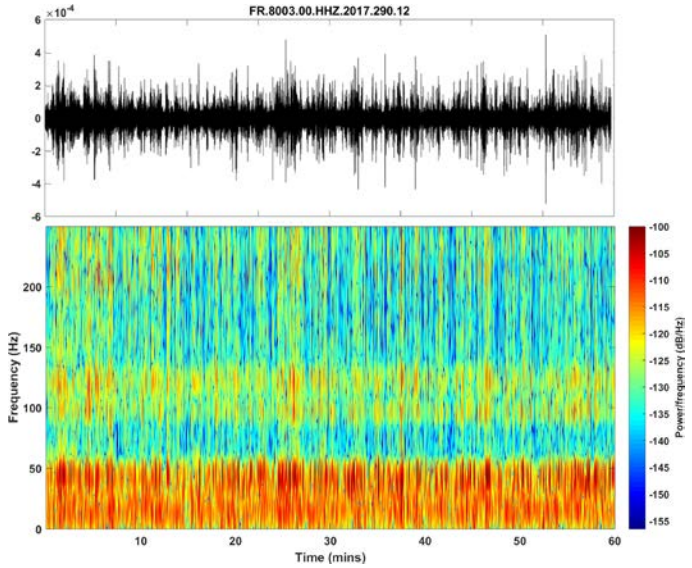
Example of vibe shot recordings (1hour)



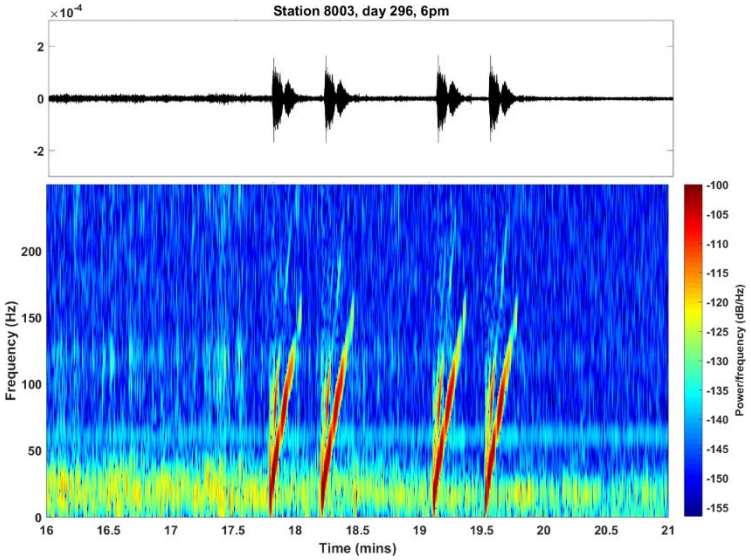
Pump running ? (3min)



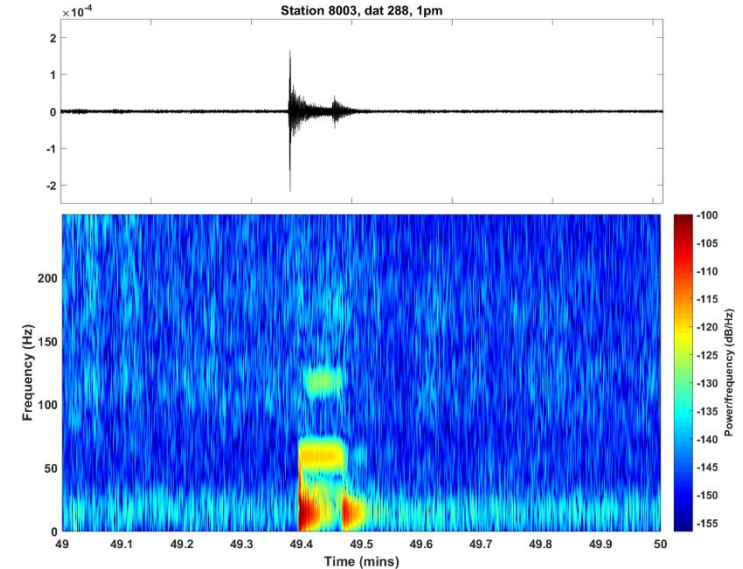
1hour windy



Example of vibe shot recordings (5min)

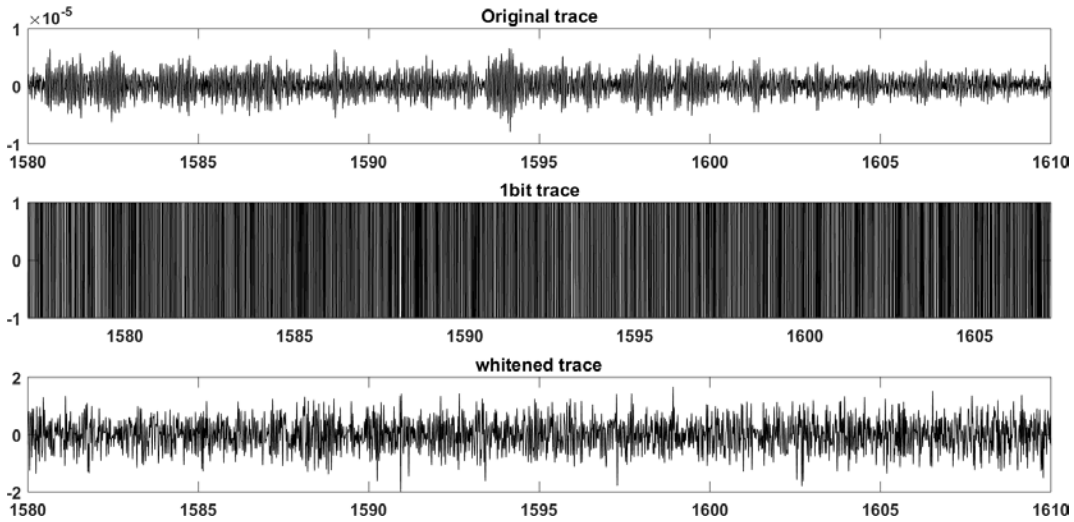


?? (3min)



Data processing

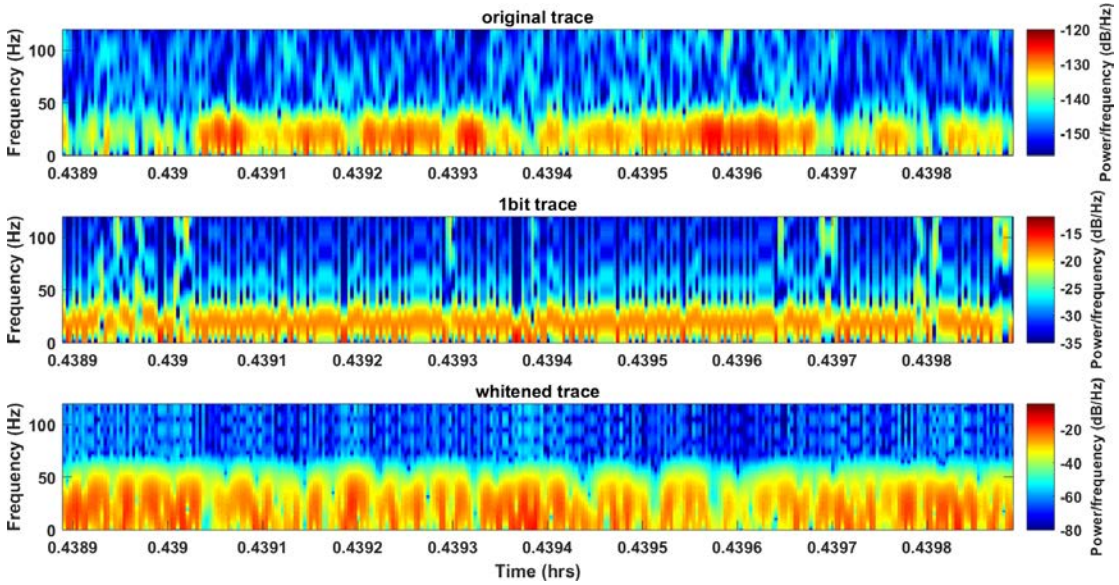
Noise



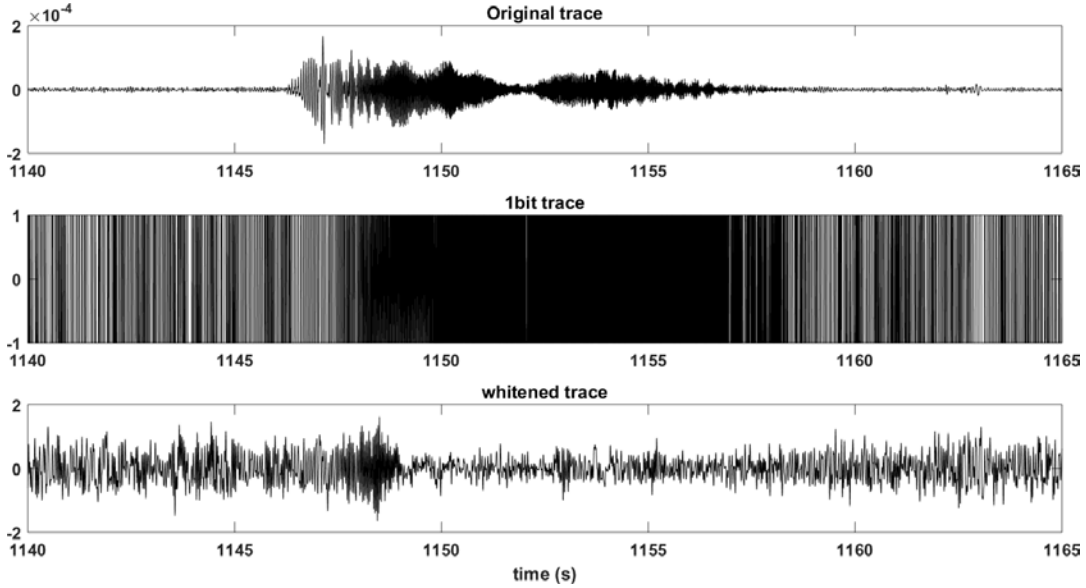
Raw

1bit

Spectral whitening



Vibe shot



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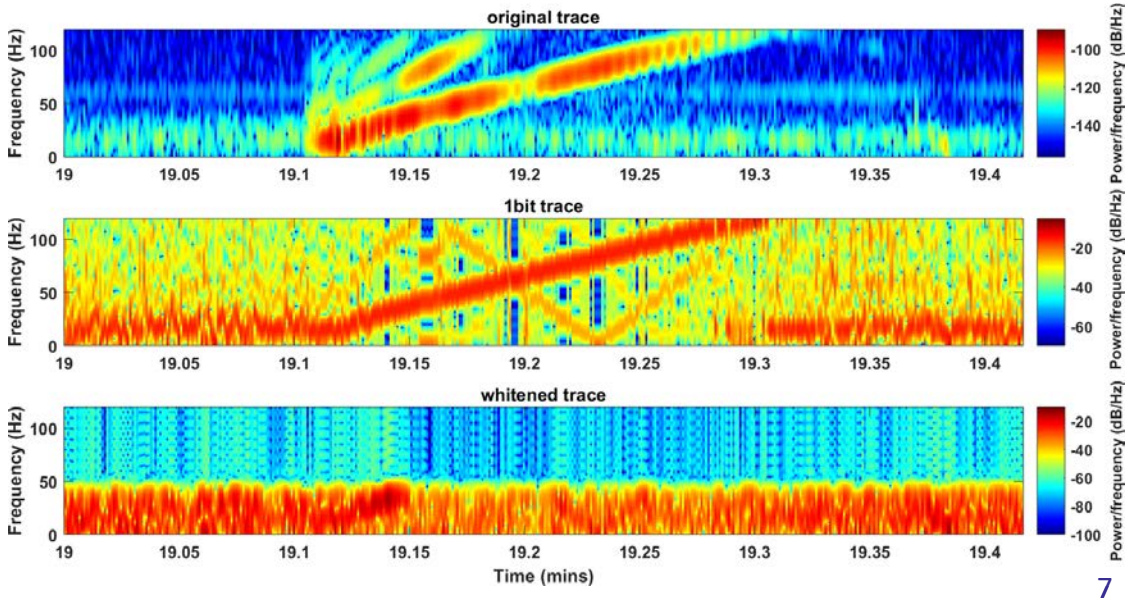
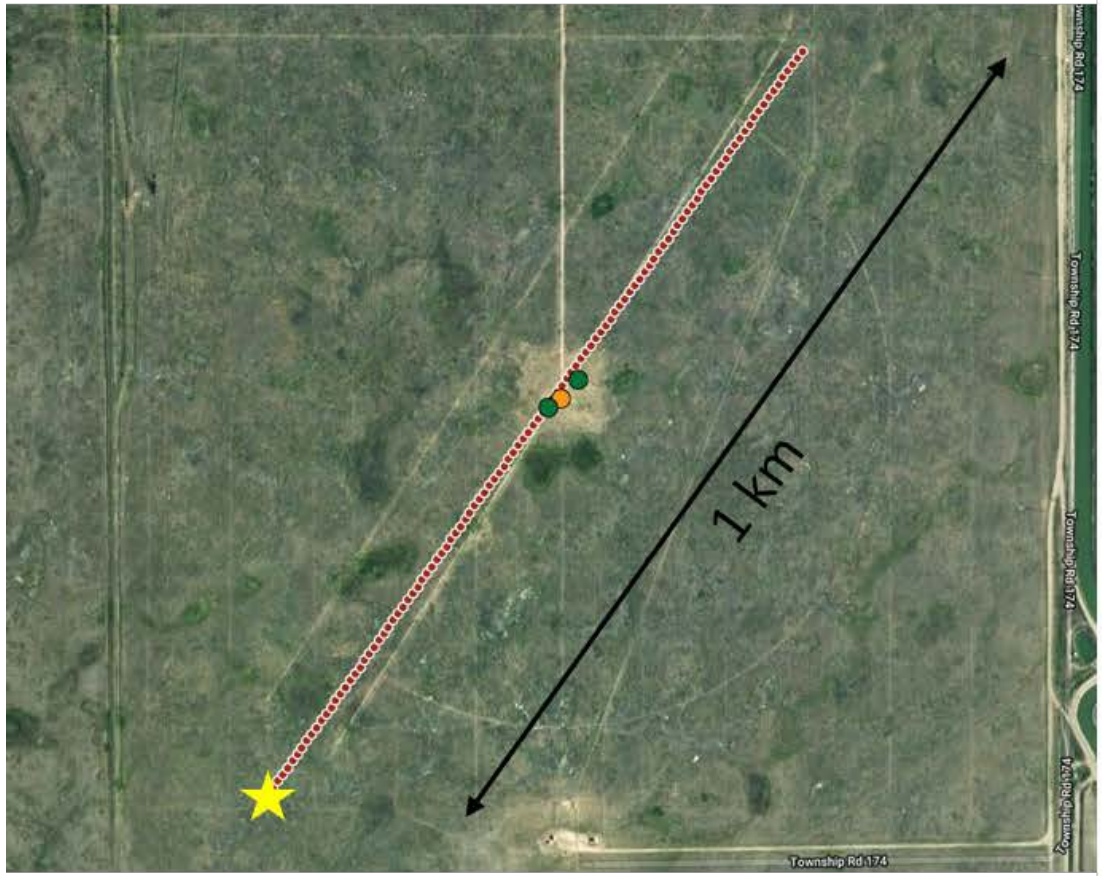
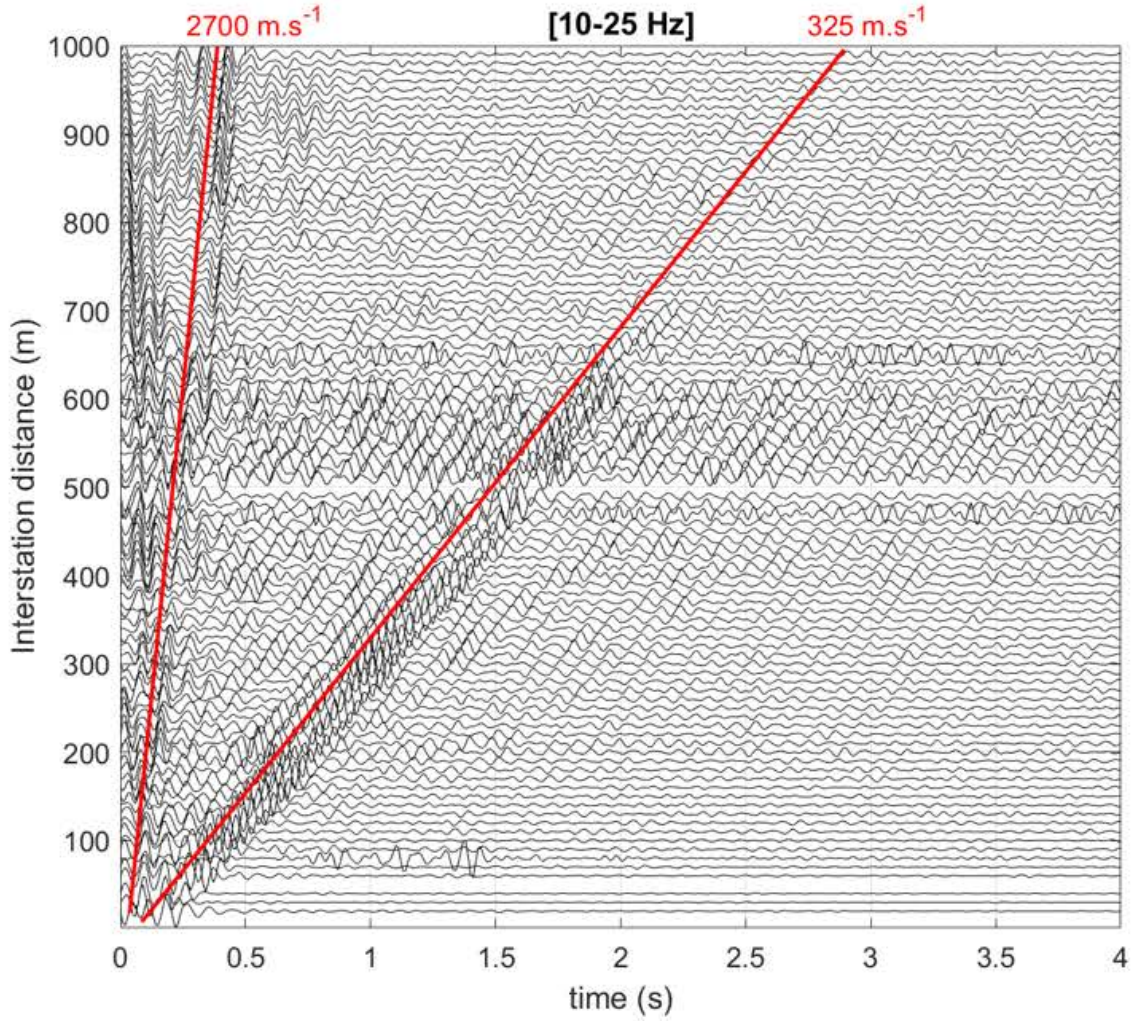


Tomography – Virtual shot gather

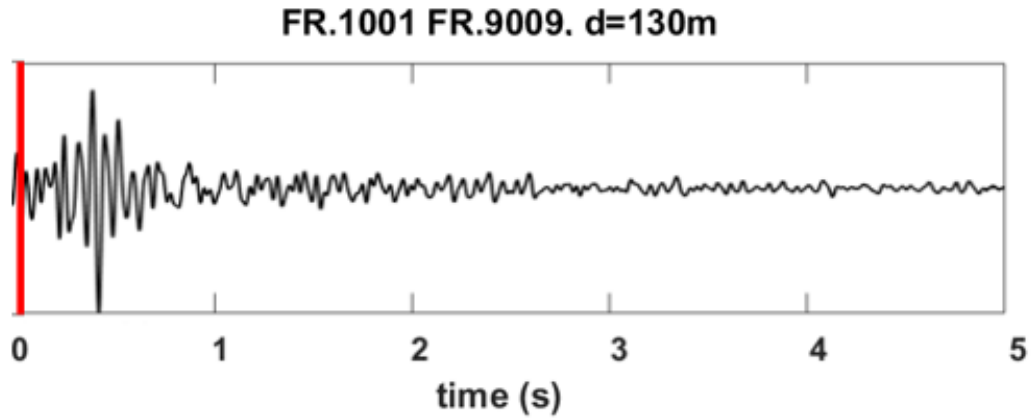
MSNoise Python code (Lecocq et al., 2014)

Processing : mean and trend removal, filtering, 1-bit normalization, spectral whitening



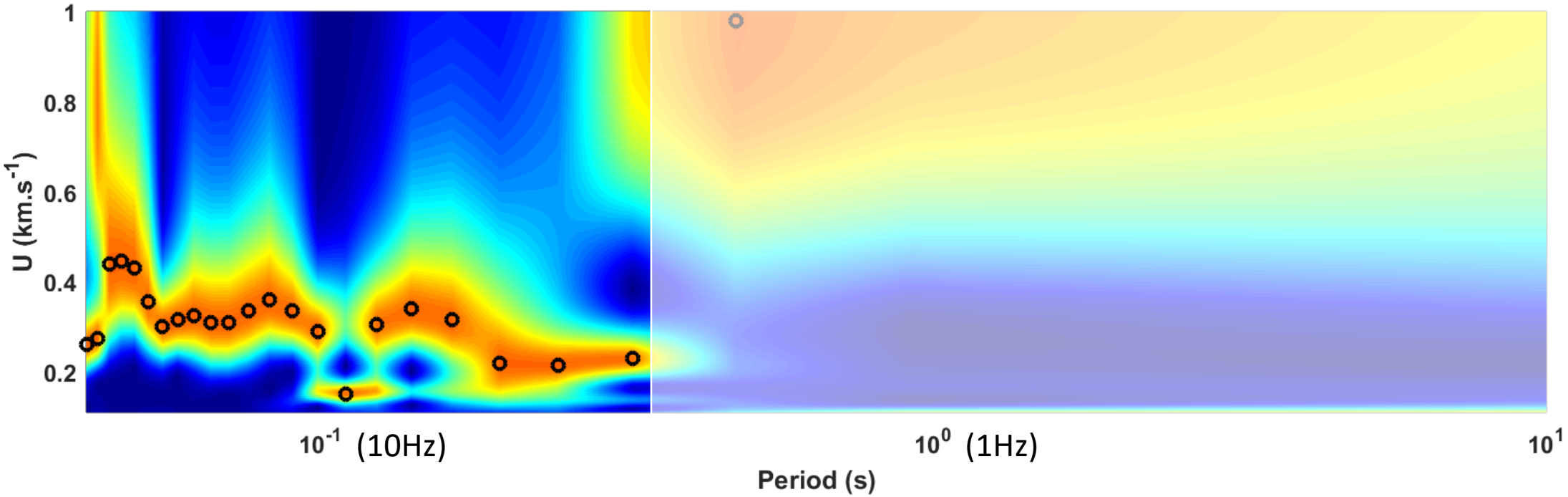


Tomography – Dispersion curves (FTAN)



Selection:

- Signal to noise ratio > 5
- $\lambda > 1$ interstation distance



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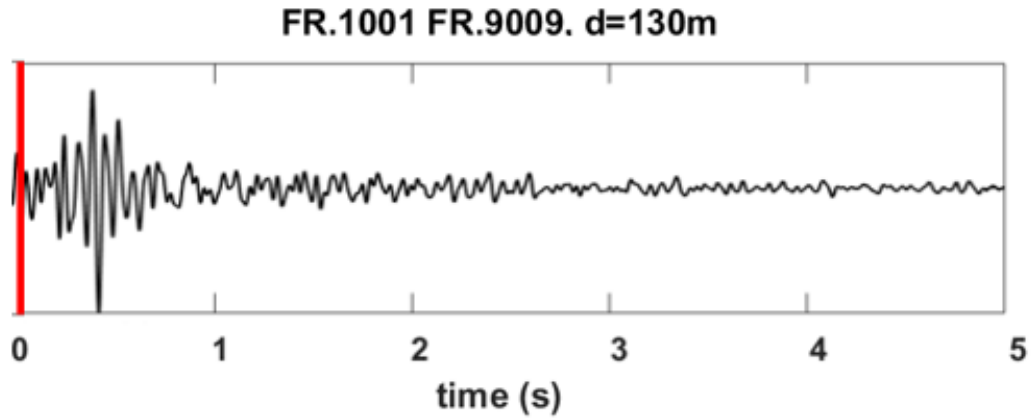

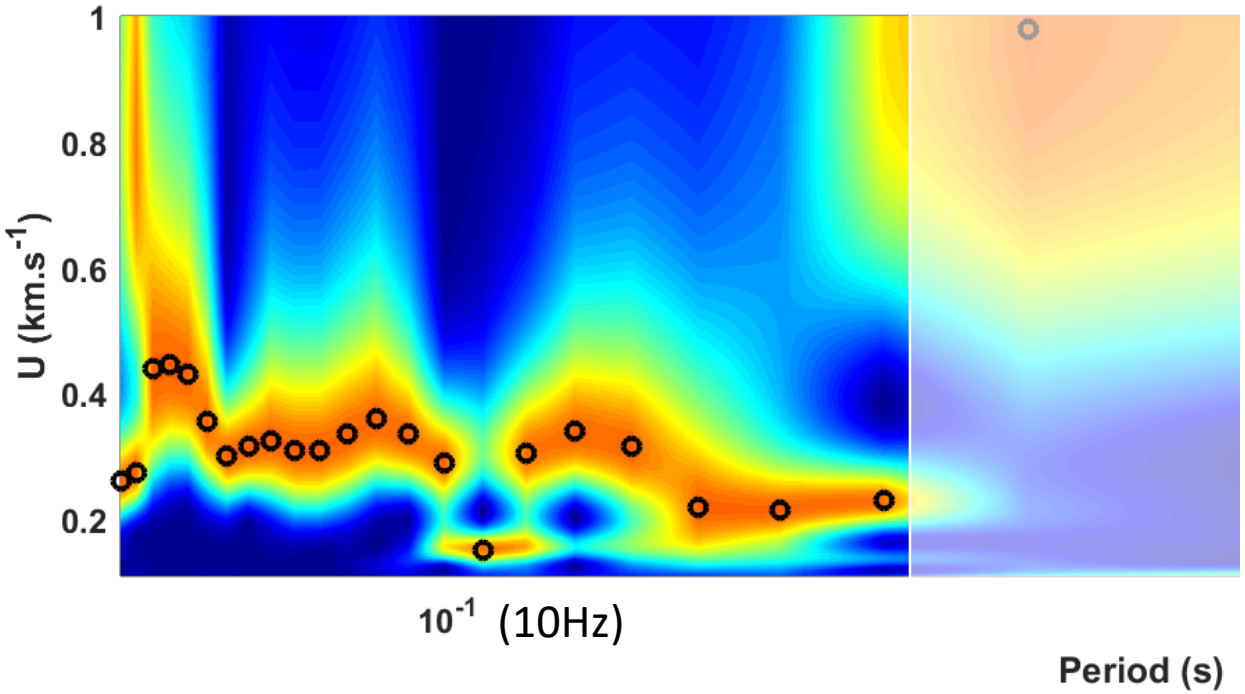

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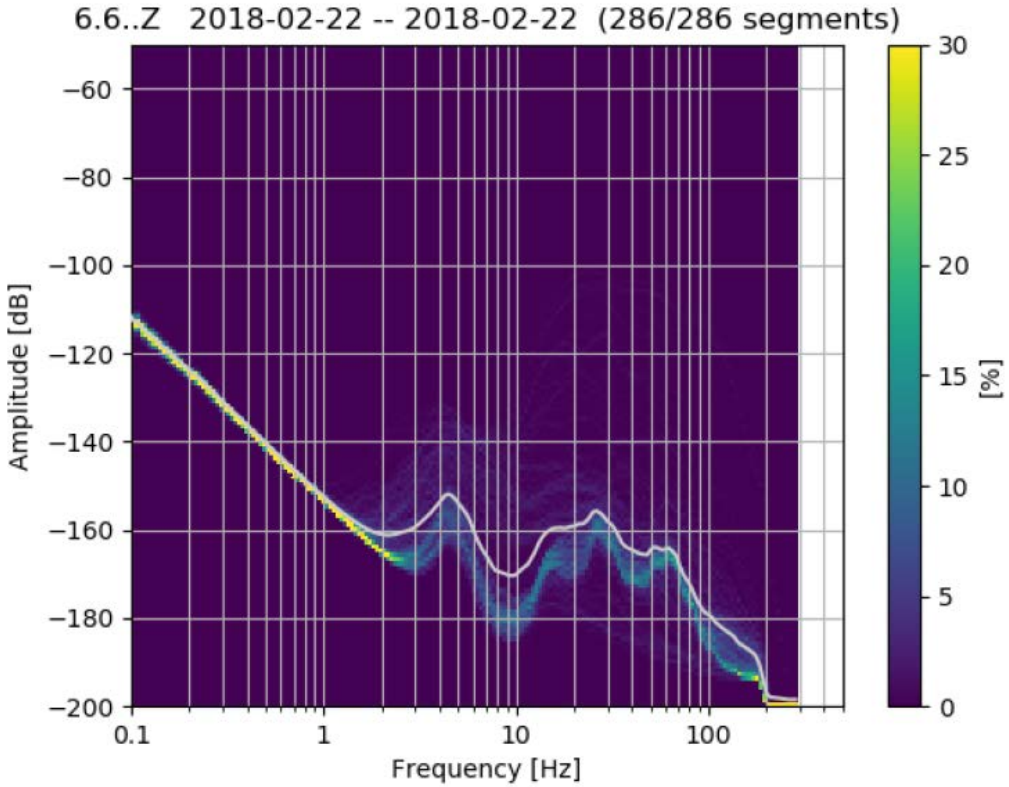
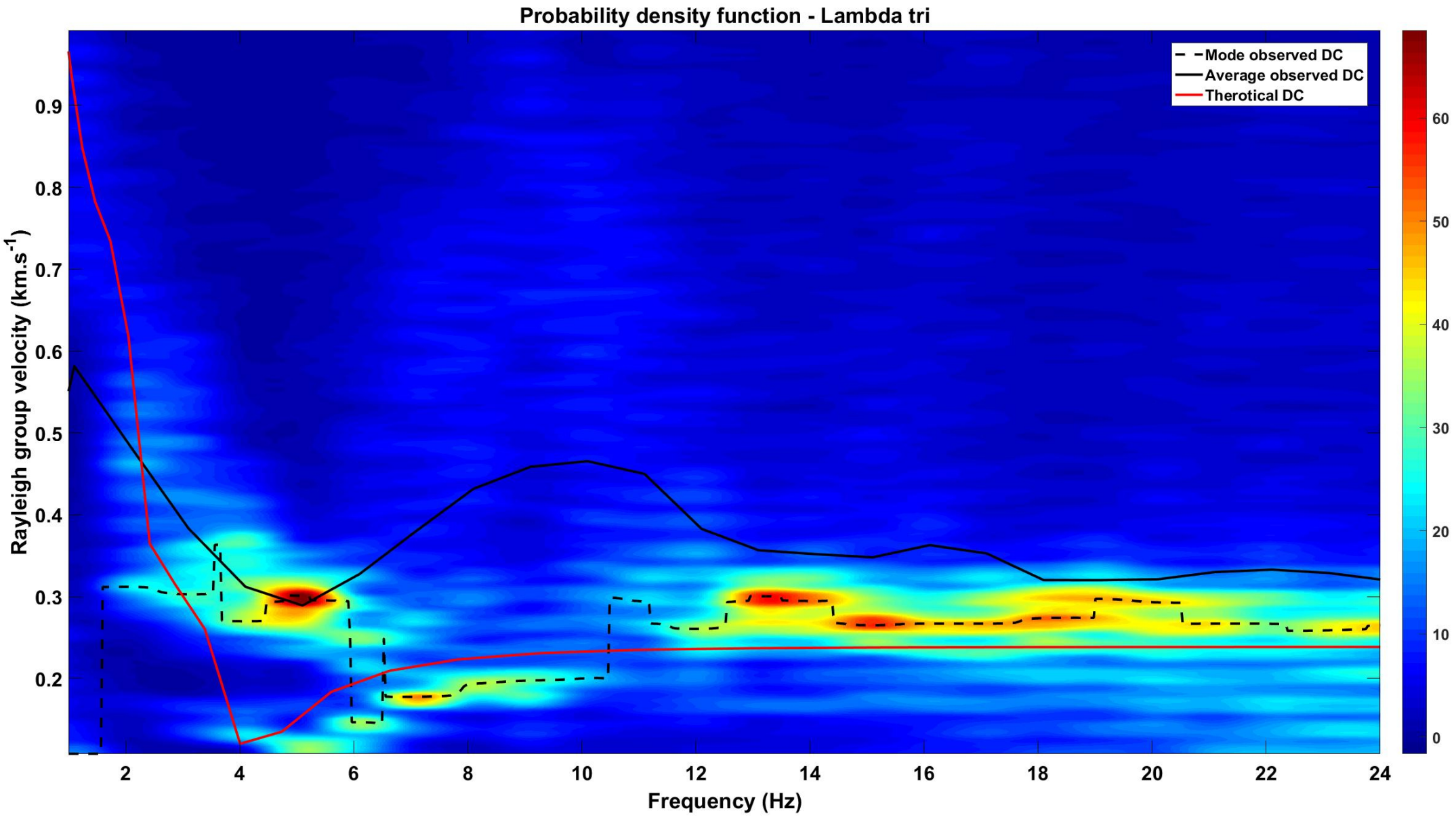
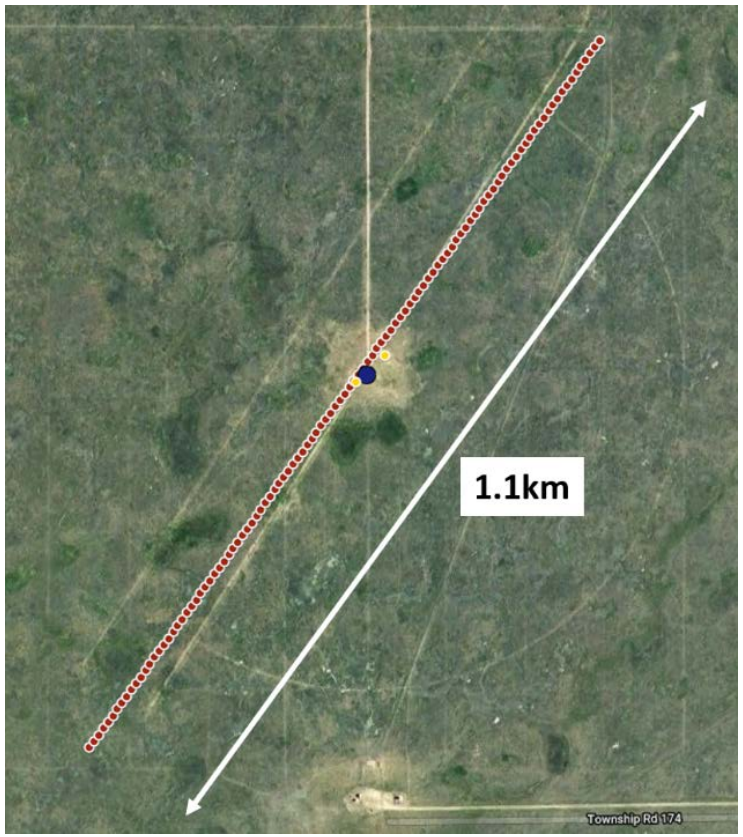


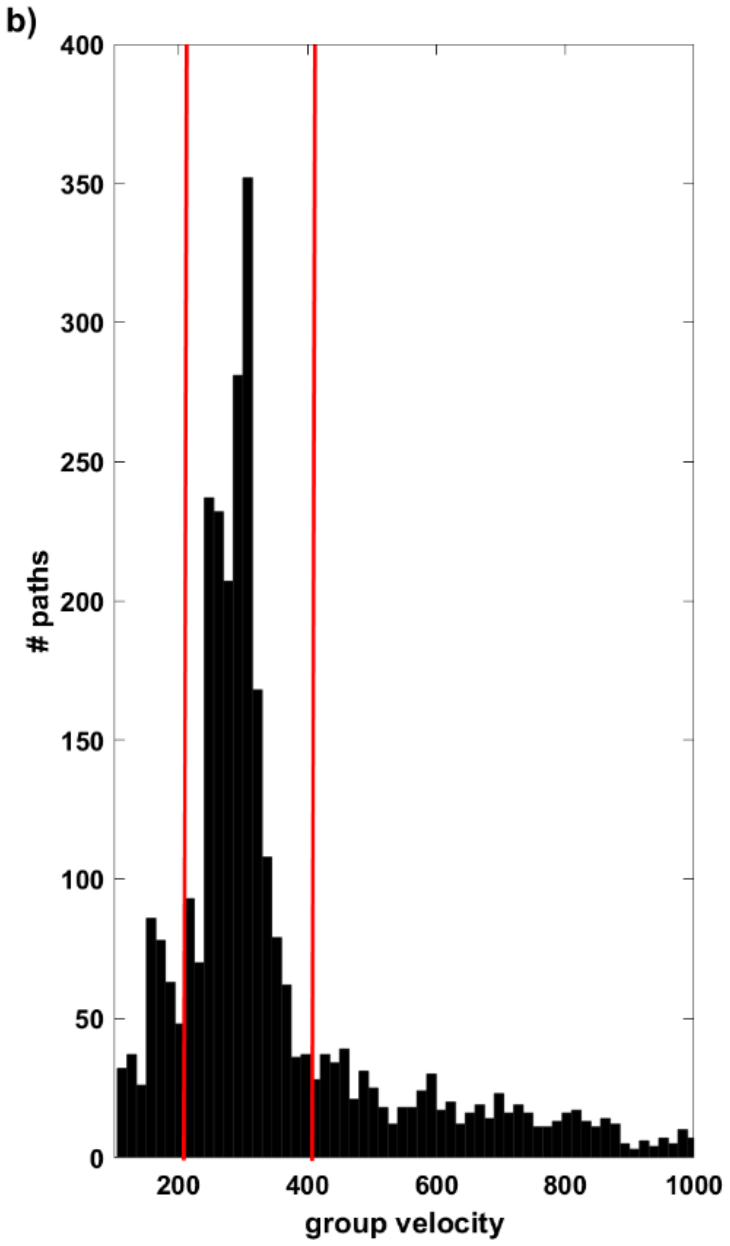
Tomography – Dispersion curves – Rayleigh wave group velocity



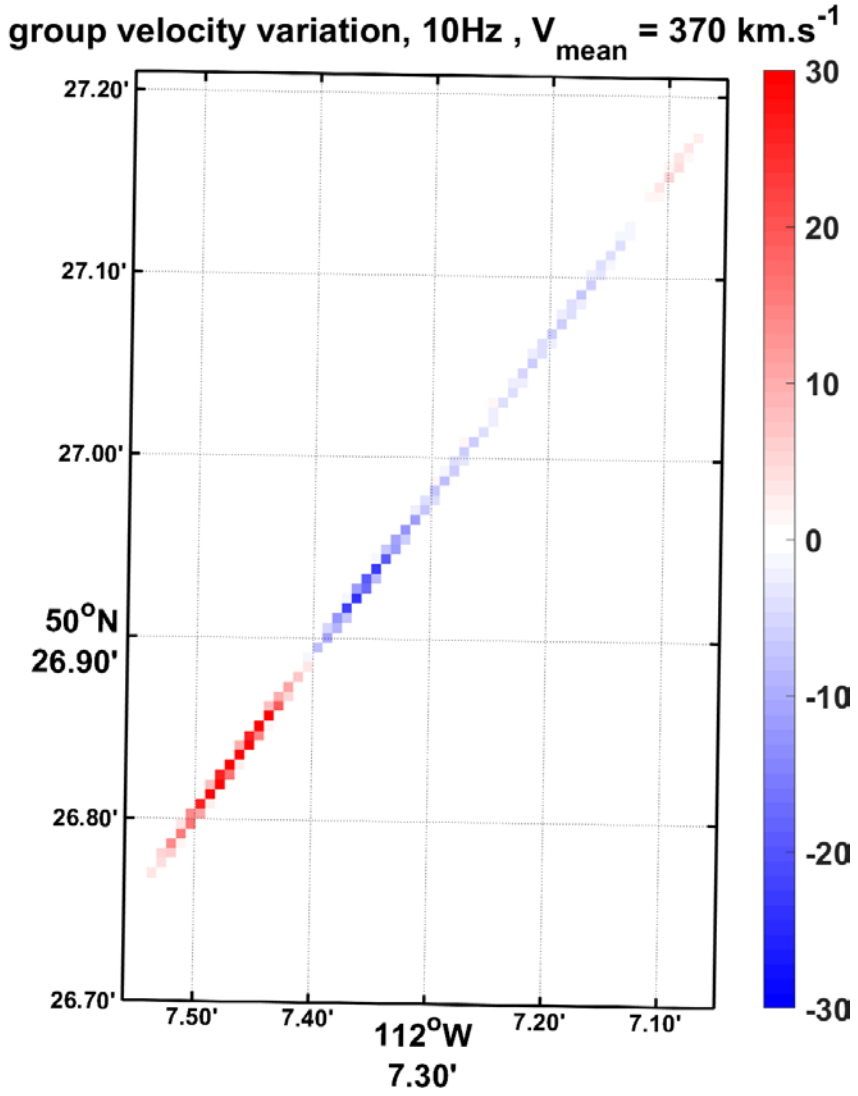
Tomography – Group velocities regionalization

10 Hz example, ~ 3000 paths



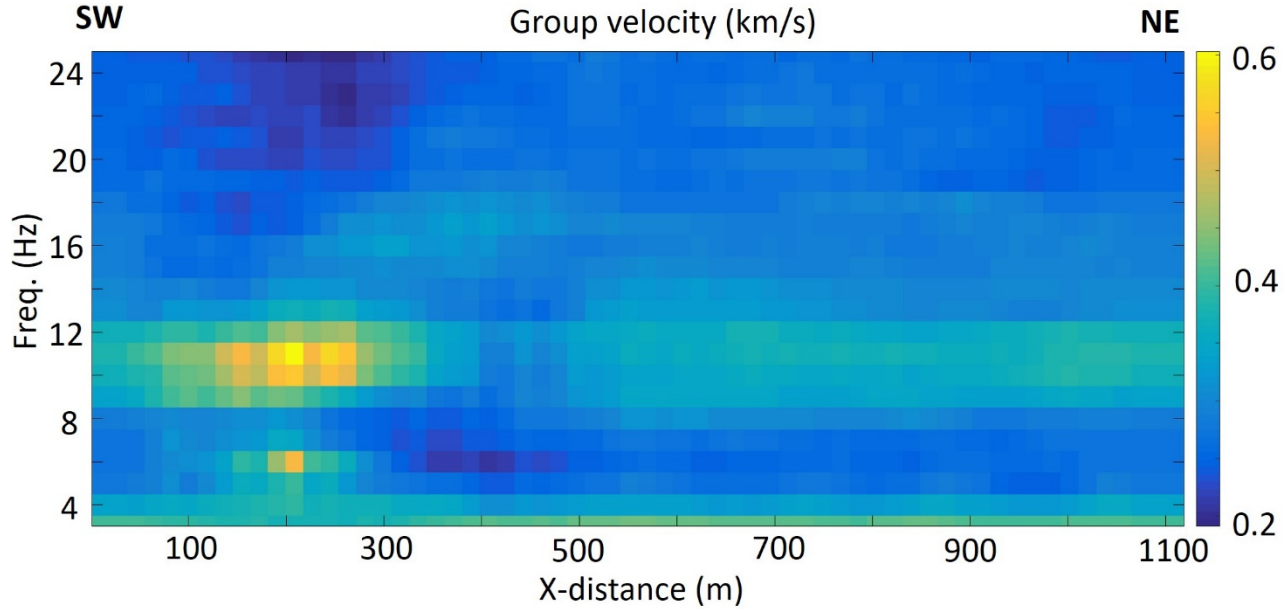


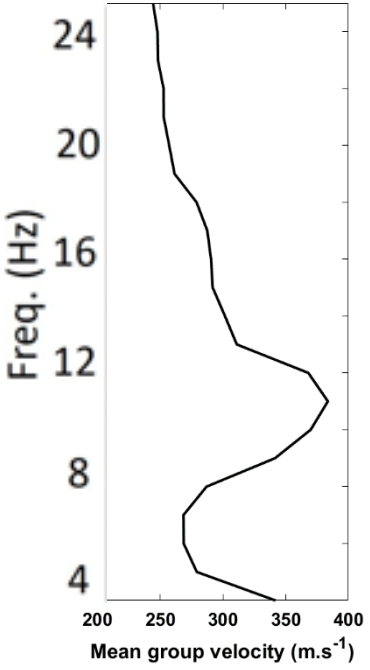
$$S(m) = (G_m - d)^T C_d^{-1} (G_m - d) + m^T G_m$$

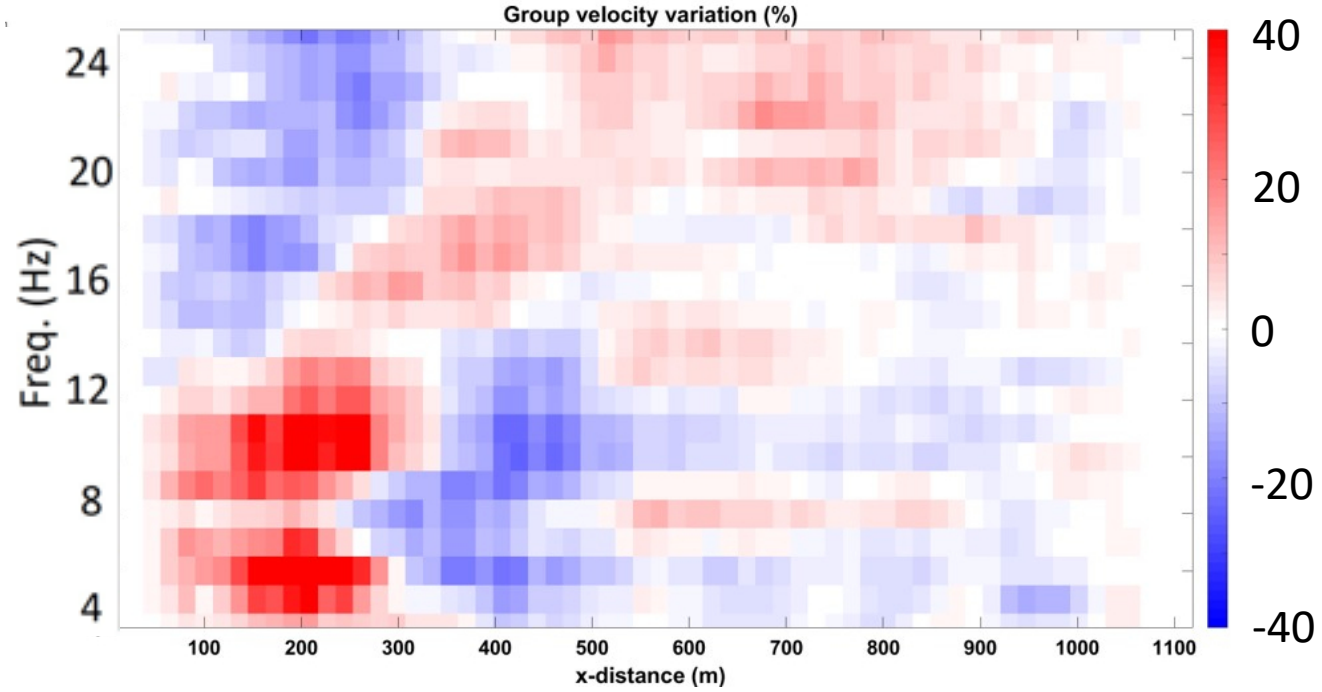


Tomography – Group velocities 2D section

a)





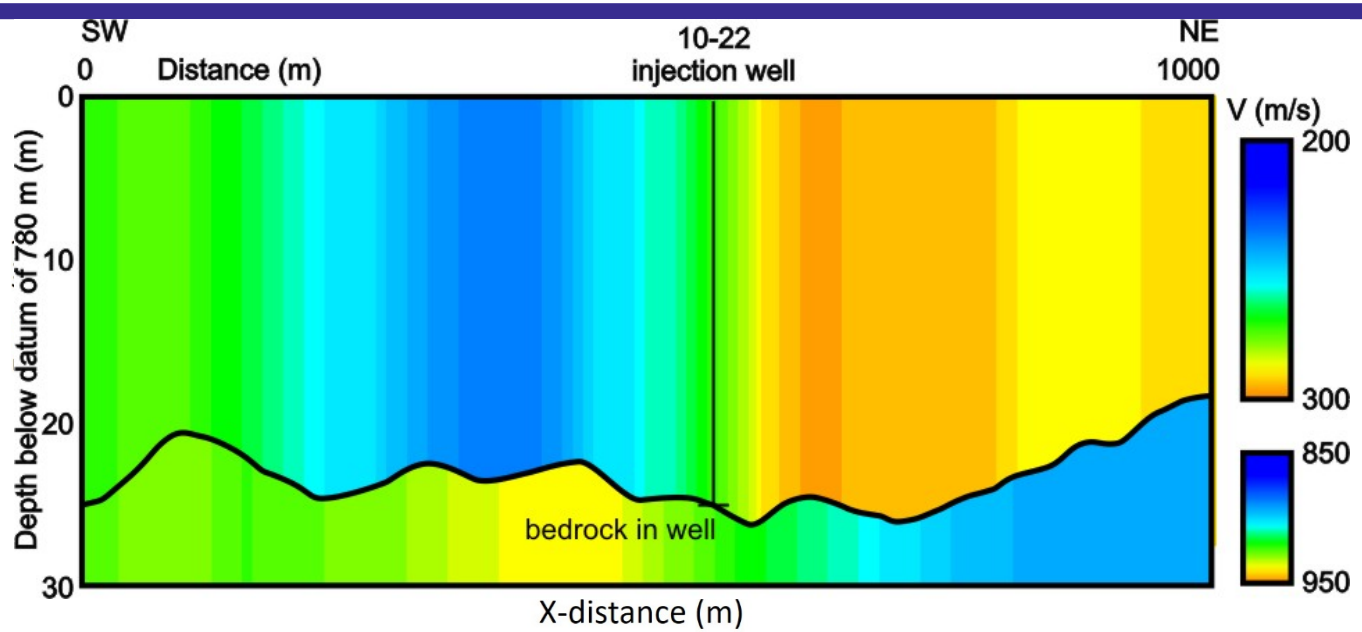


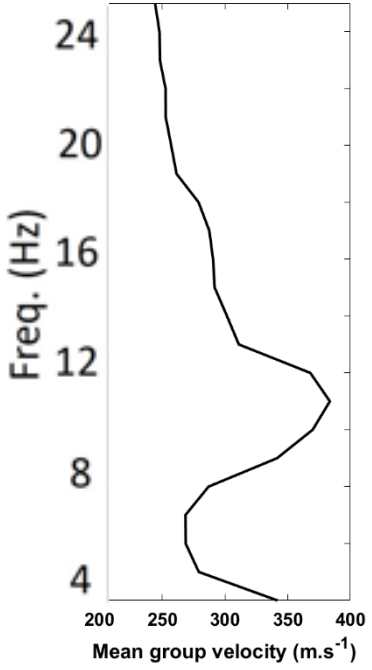
At high frequencies (shallow depth) : lower velocities on the SW part.

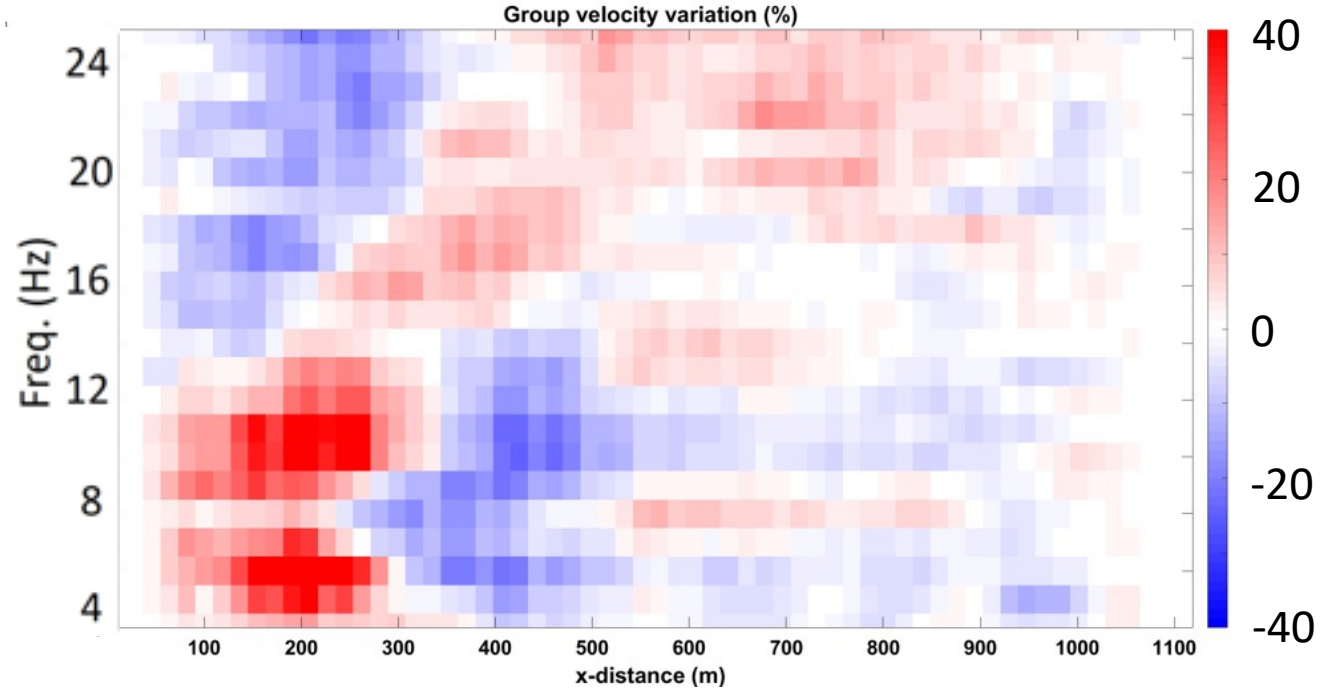
At low frequencies (deeper part) : higher velocities on the SW part.

Tomography – Group velocities 2D section

a)



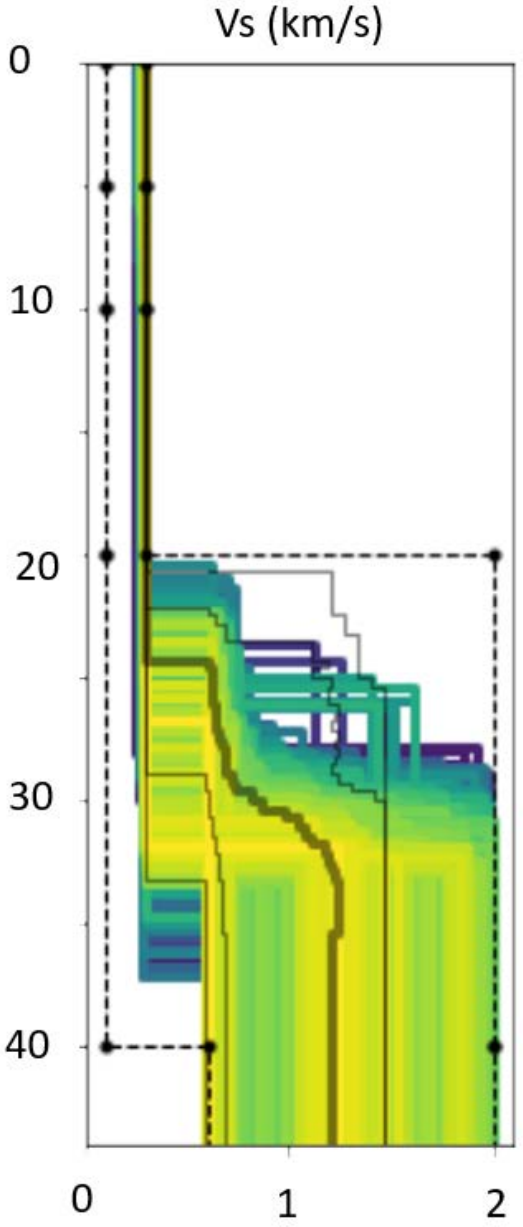




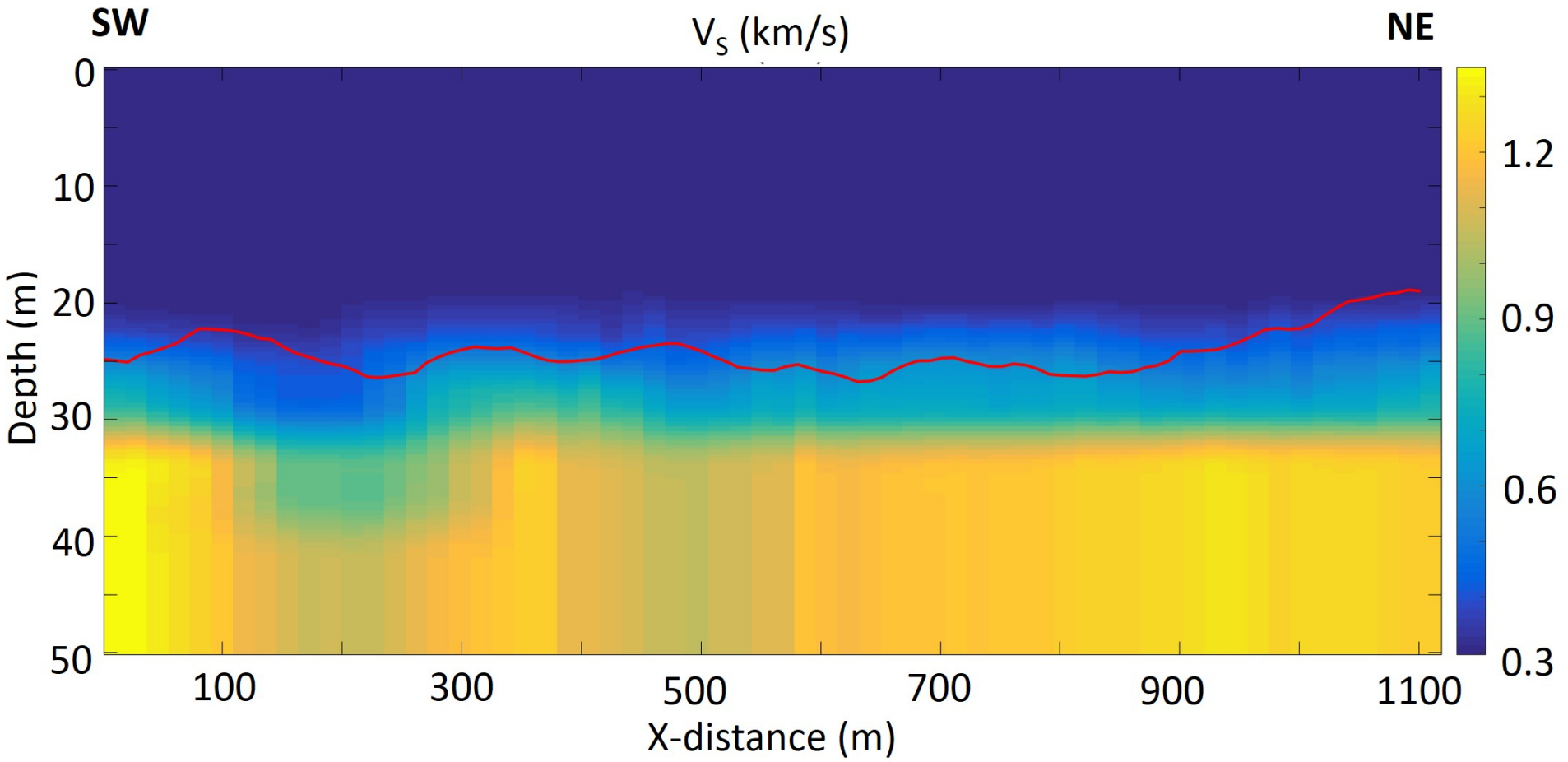
At high frequencies (shallow depth) : lower velocities on the SW part.

At low frequencies (deeper part) : higher velocities on the SW part.

Tomography – Local dispersion curve inversion

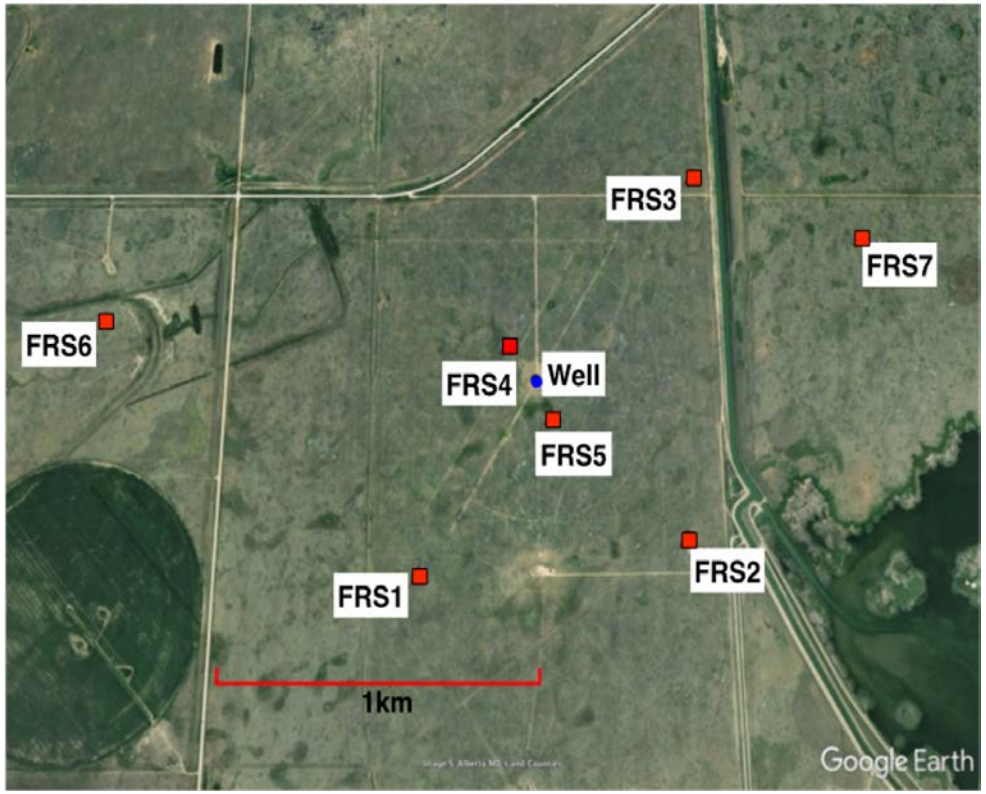


Markov Chain Monte Carlo inversion

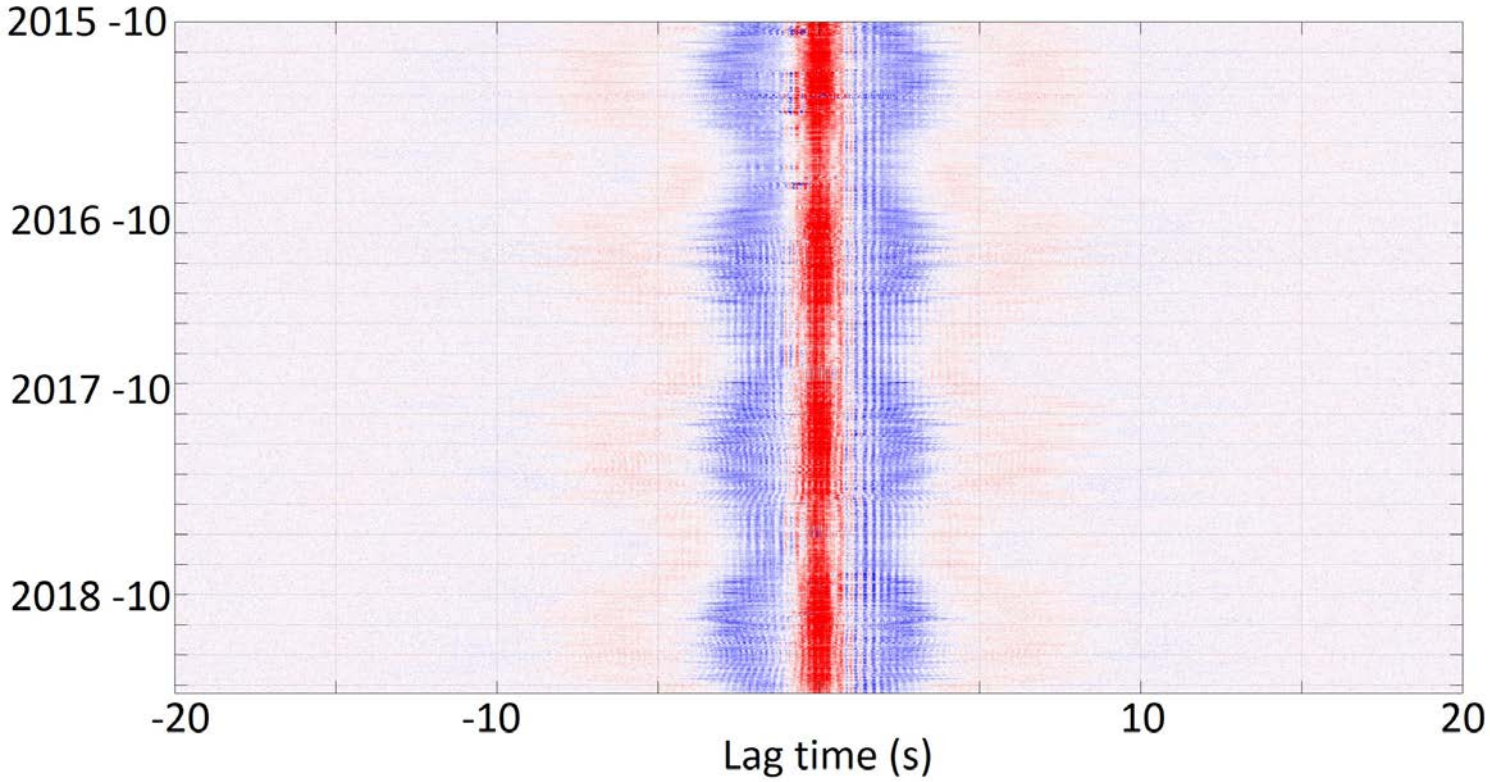


Monitoring – Daily correlations

Since October 2015
on 7 broadband stations

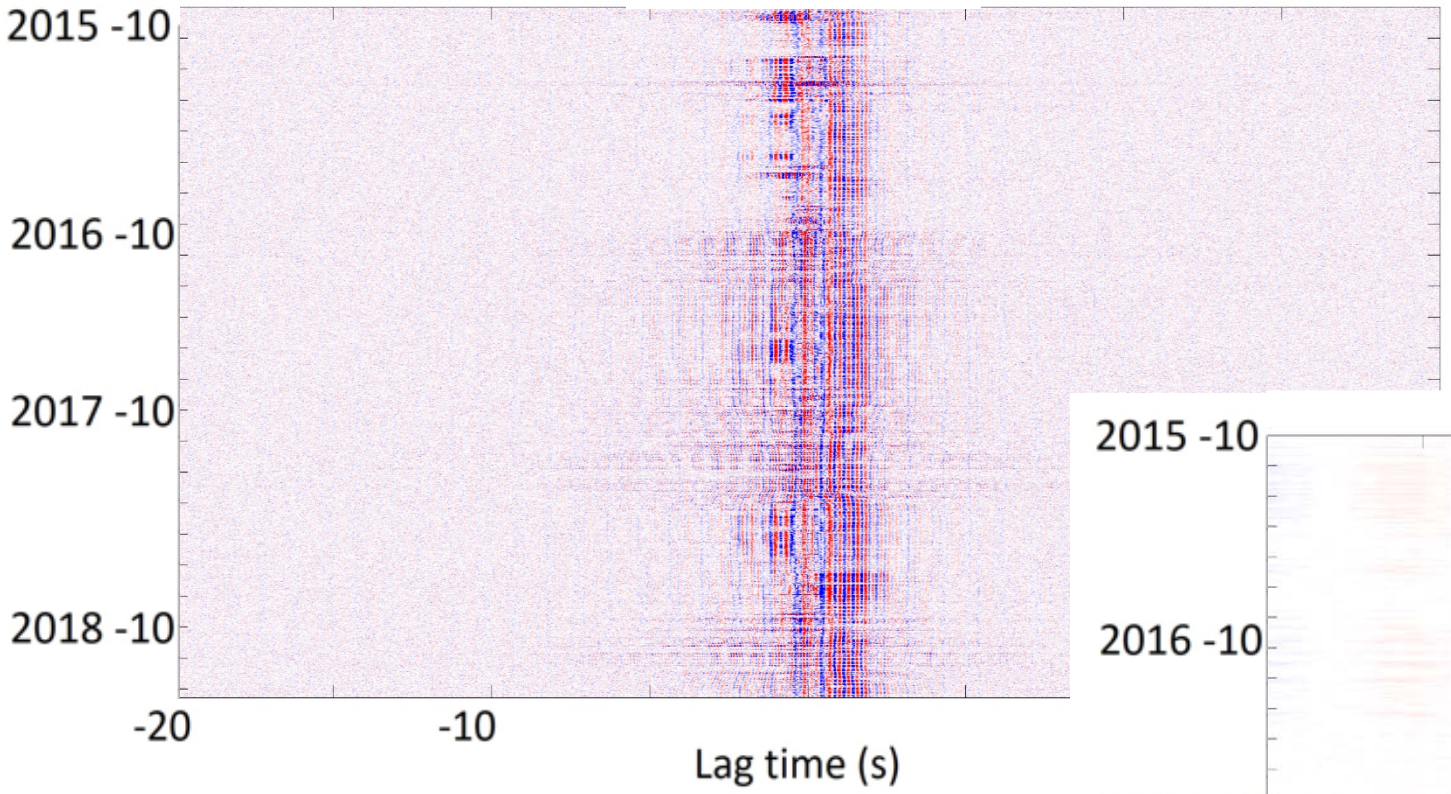


Daily correlation between FRS4 and FRS5 - [0.1-40]Hz

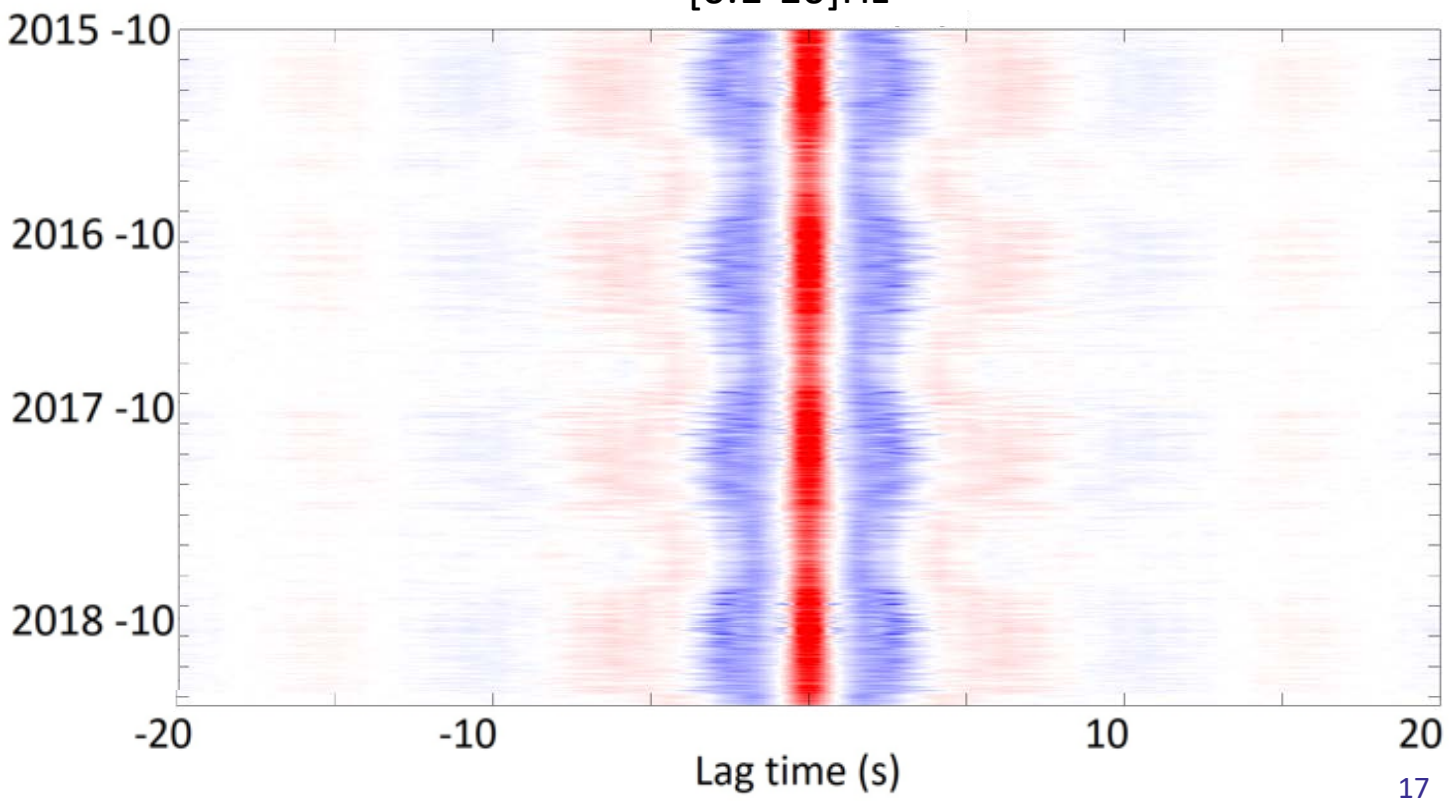


Monitoring – Daily correlations

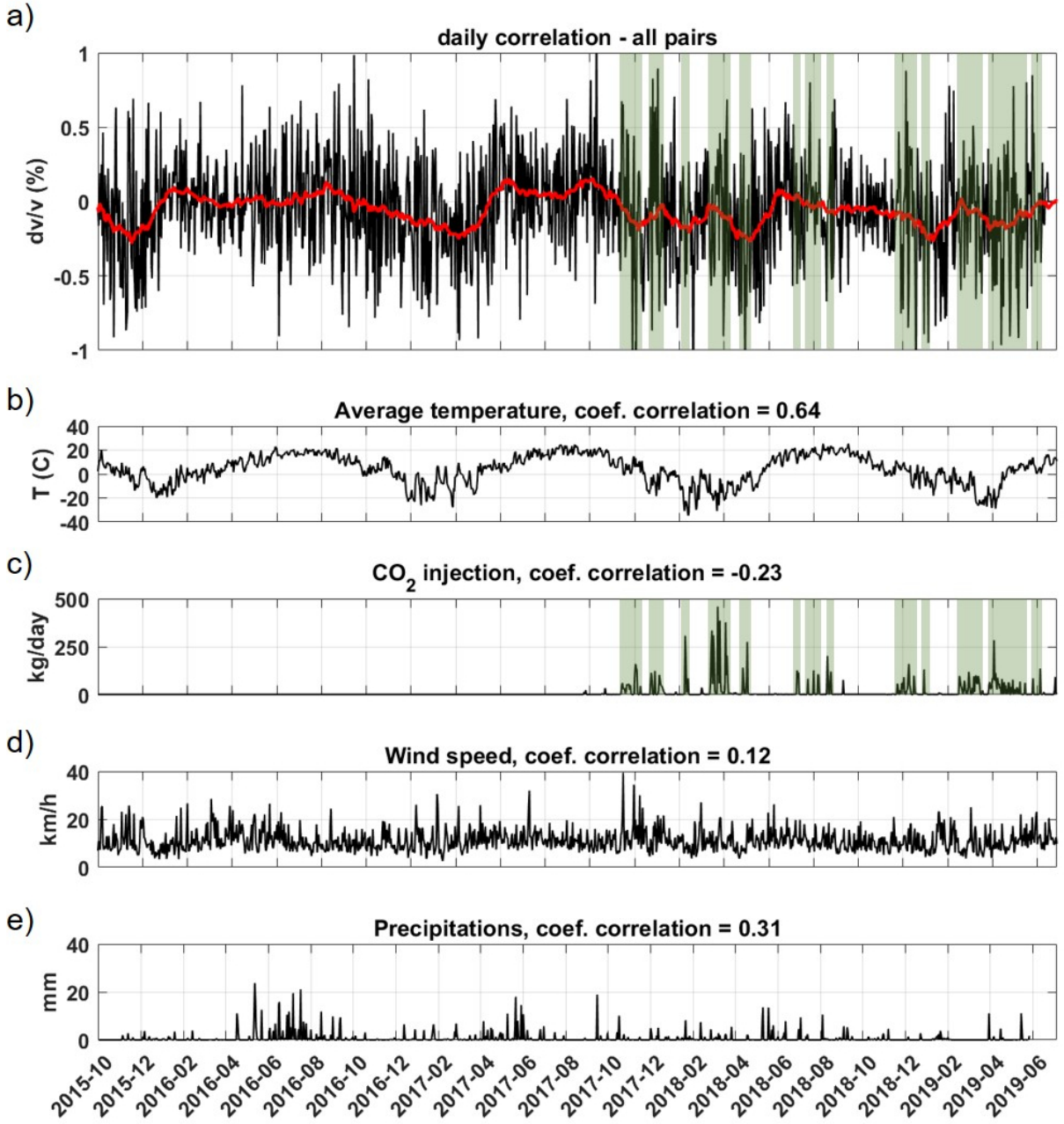
[1-10]Hz



[0.1-10]Hz



Monitoring – Velocity variations



- Moving-Window Cross Spectrum Analysis, [0.1-1]Hz frequency range, from 0.5 to 5s
- good correlation between the smoothed dv/v curve and the average temperature
- CO_2 injection periods seem to correspond to periods of velocity variation decreasing

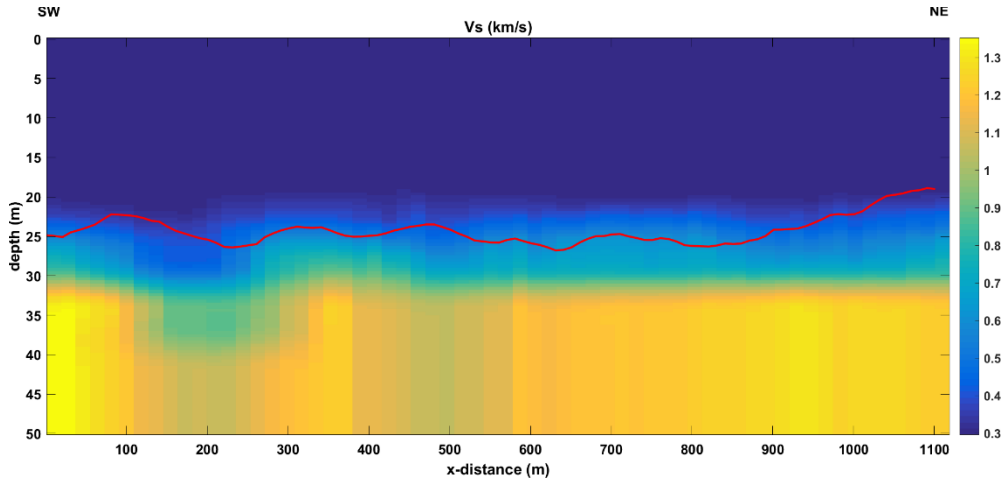
Conclusions

Tomography

Coherent results with other methods.

Future work includes:

- Process the June 2019 survey to have the 3D near surface image
- Compare Winter (Feb 2018, this study) and Summer time (June 2019 survey)

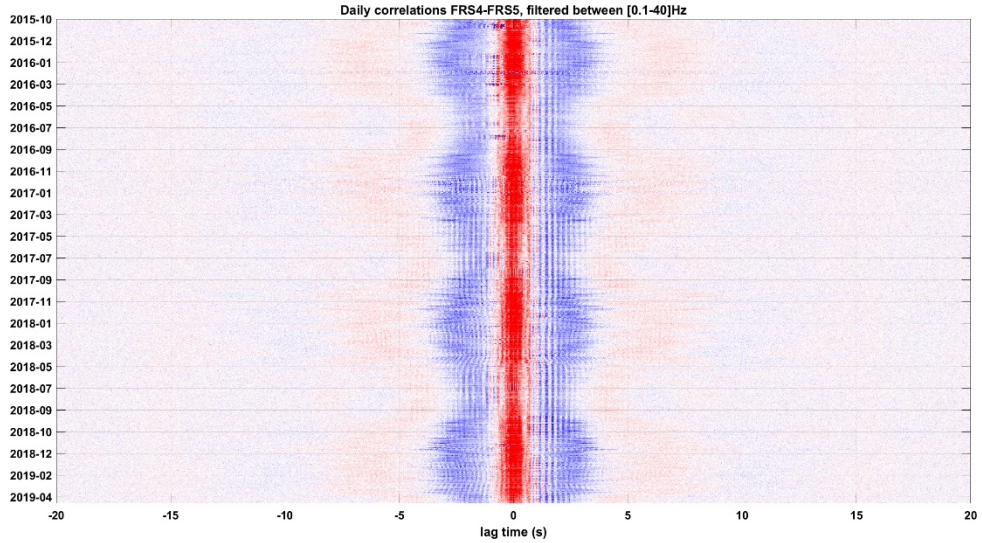


Monitoring

Clear effect of ambient temperature, possible effect of CO_2 injection

Future work includes:

- Better understand the effect of each variable on the velocity variation
- Add the 24 geophones which are recording since June 2019



Conclusions

At the Field Research Station

- Several datasets for baseline characterization (for near surface tomo and study how environmental changes may affect the Green's function reconstruction)
- High quality of daily correlations (we should consider trying hourly correlation)
- Very challenging field as the expected changes in velocity are small

In general – Using ambient noise for CCS monitoring

- All the theory/tools are already developed
- Fully continuous monitoring
- The data can be easily acquired, especially with the study of microseismicity, but can quickly reach very large volume
- Quality of body waves is still not here (yet) but others applications are already here
- Low cost, easy to deploy, easily repeatable and environmentally friendly

Acknowledgments

- This research was undertaken thanks in part to funding from the Canada First Research Excellence Fund;
- CaMi.FRS JIP subscribers ;
- CREWES sponsors ;
- Bristol University (A. Storke and M. Kendall for access to the broadband data) ;
- NSERC -grant CRDPJ 461179-13 ;
- Cenovus Energy and Torxen Energy for providing access to the site;
- Fieldwork help.