Ambient noise correlation study at the CaMI Field Research Station, Newell County, Alberta, Canada

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CREWES Annual Sponsors Meeting, Banff, Ab, CA

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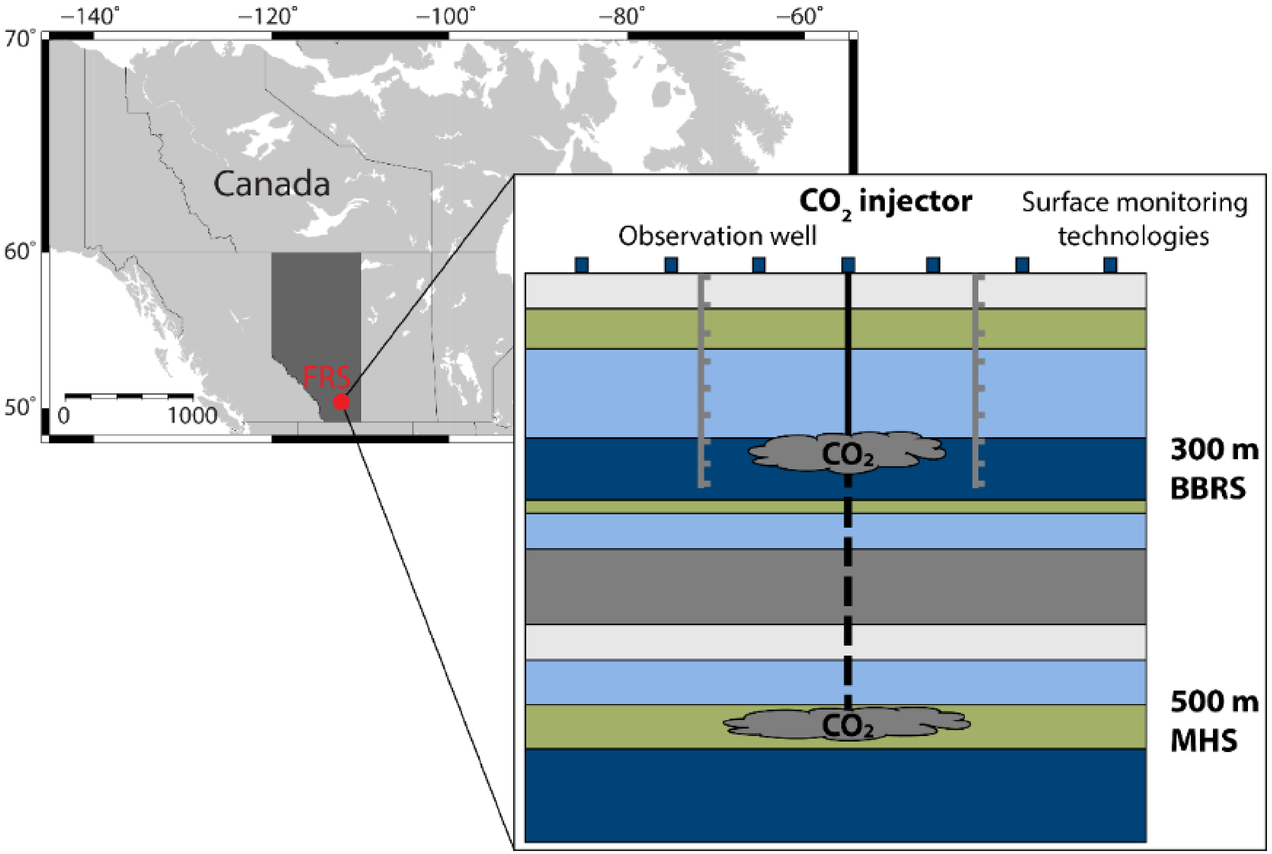
NSERC CRSNG
CMC Containment & Monitoring Institute
UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
Department of Geoscience

CaMI Field Research Station - Objectives

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.

CaMI Field Research Station - Location



=> Injection of a small amount of CO_2 (<400/tons per year) at shallow depth (300m)

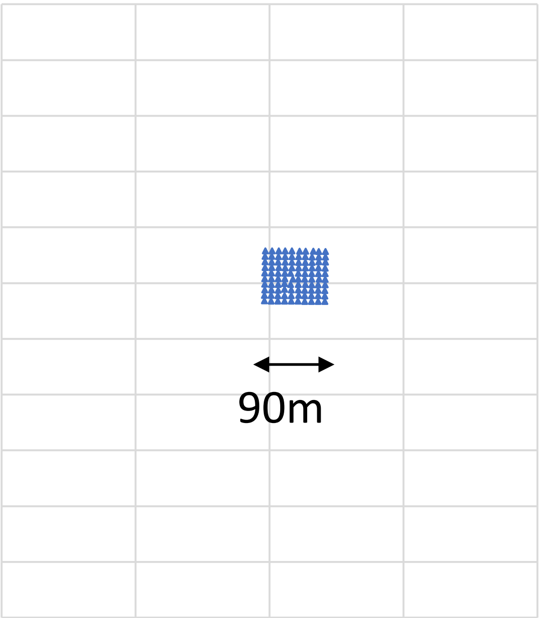
- 3D-3C (100mx100m) permanently installed geophones;
- permanent sources (Tyler Spackman)*;*
- 112 electrical resistivity tomography (ERT) electrodes;
- distributed acoustic sensing (DAS) straight and helical fiber optic cables (Adriana Gordon, Kevin Hall, Kris Innanen)*;*
- 24 geophones deployed in one of the observation well for VSP studies (Adriana Gordon, Kevin Hall)*;*
- 2D and 3D surface seismic surveys (Helen Isaac, Don Lawton);
- Cross-well seismic and electromagnetic;
- Soil gas monitoring;
- **Continuous seismic data**;
- And more

How can we detect the plume ? How soon ?

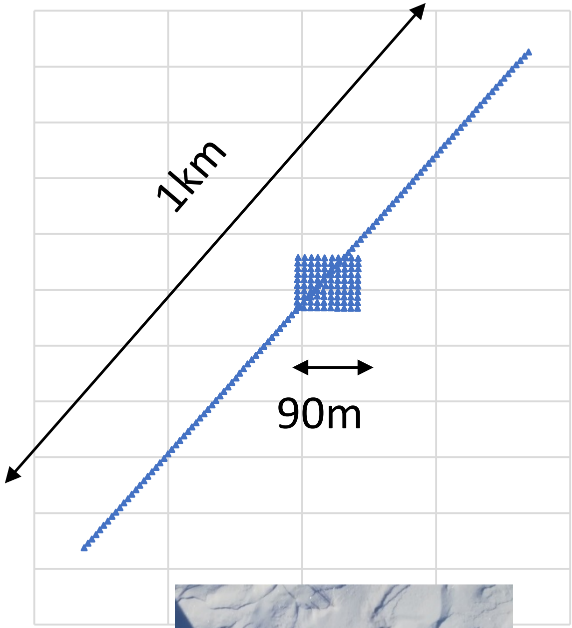
Continuous recording of seismic ambient noise

“Baseline”

October 2017 – 14 days
98 geophones

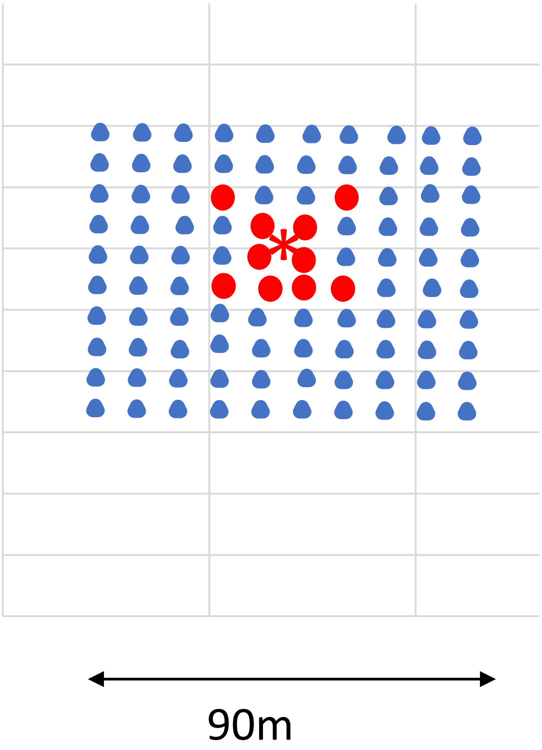


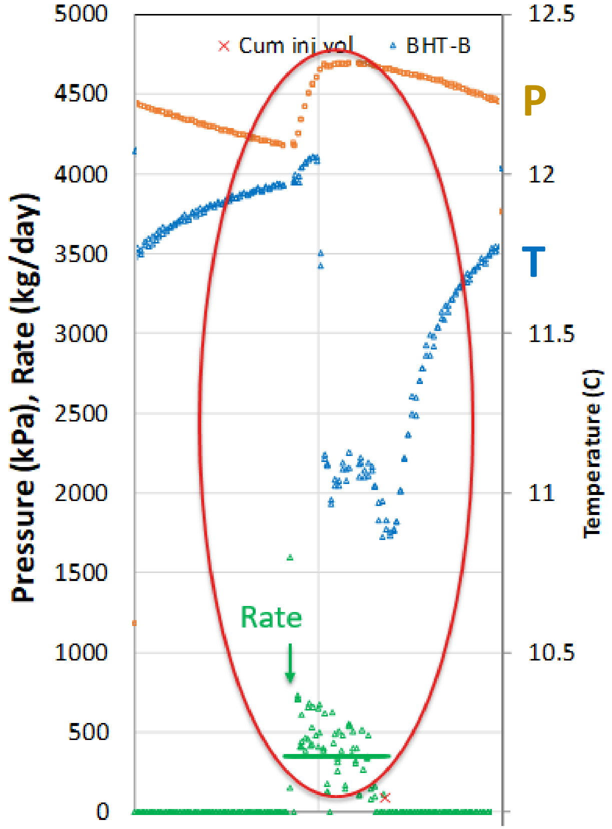
February 2018 – 25 days
201 geophones



Microseismicity due to “high” pressure injection?

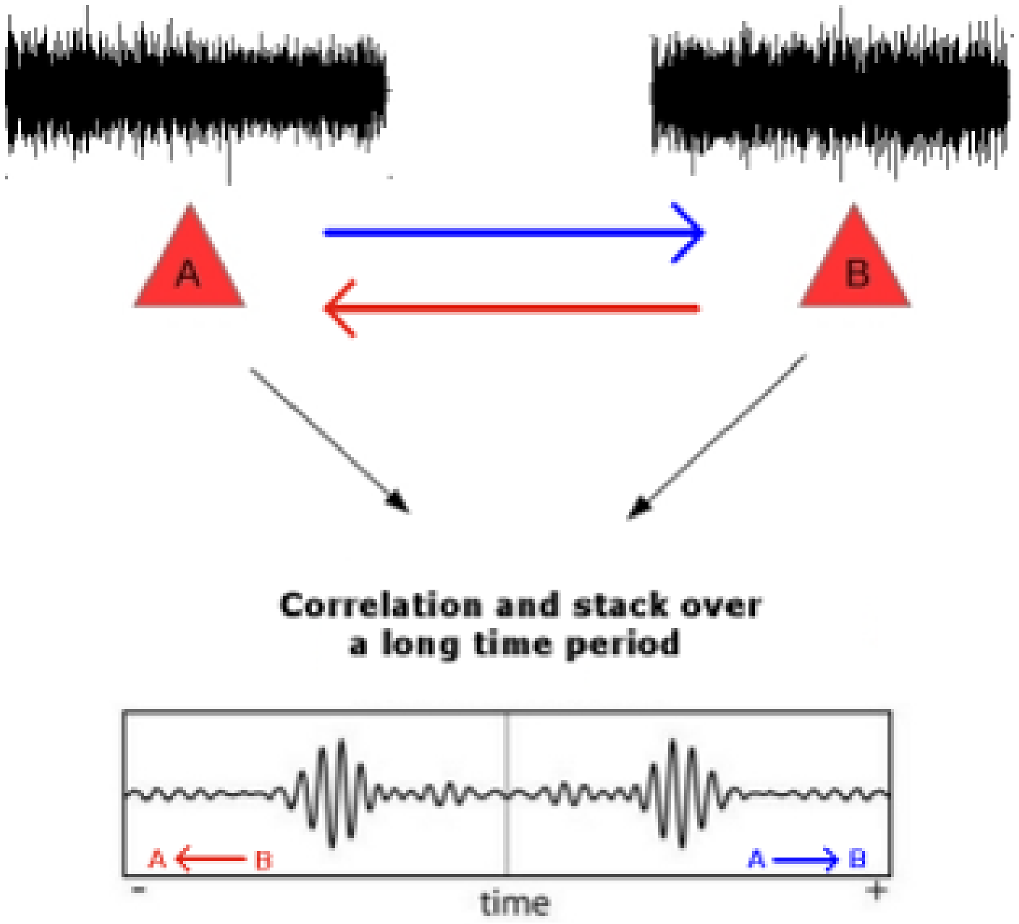
October 2018 – 7 days
10 geophones





Ambient noise correlations - Principles

Principle: Correlating the noise registered a two stations approximates the Green function between those two stations (Weaver et Lobkis (2001)).



Principle: Correlating the noise registered a two stations approximates the Green function between those two stations (Weaver et Lobkis (2001)).

Tomography

Correlation

↓

Green's function reconstruction

↓

Dispersion curve

↓

Dispersion curves regionalization

↓

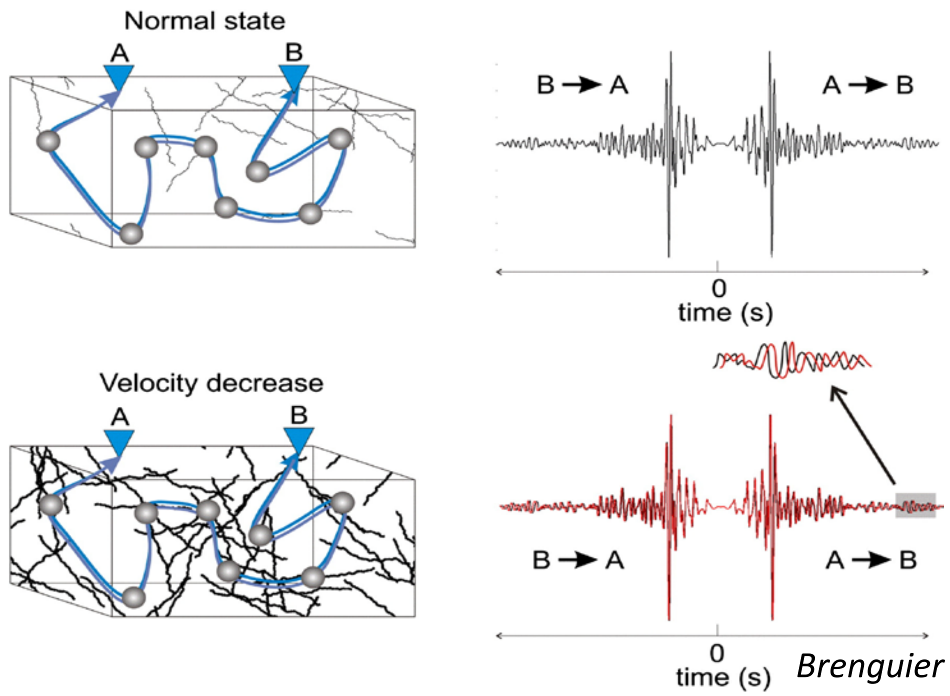
Inversion for elastic parameters

↓

3D elastic model of the subsurface

Monitoring

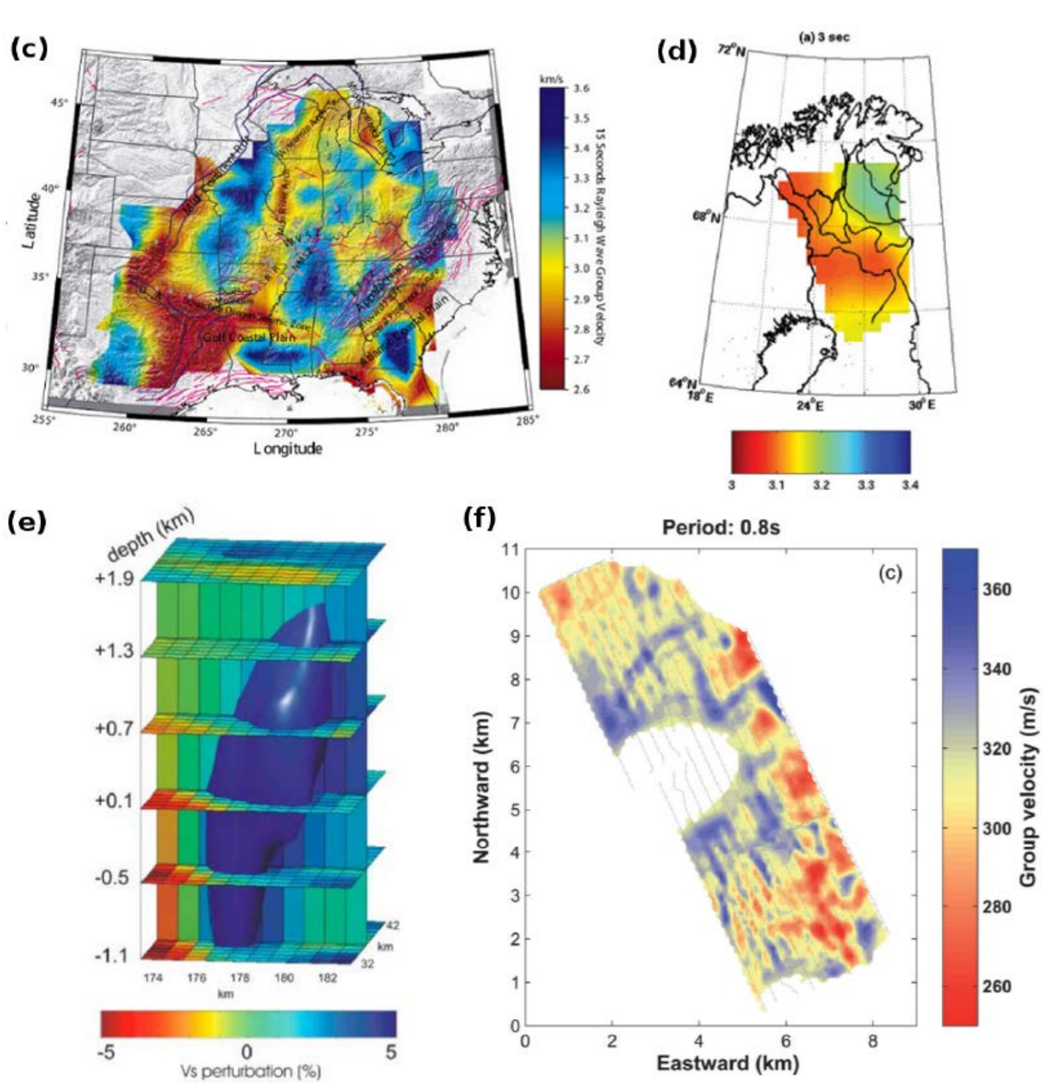
If you change the medium between the two stations, the results of the correlation will change



Brenguier et al., 2016

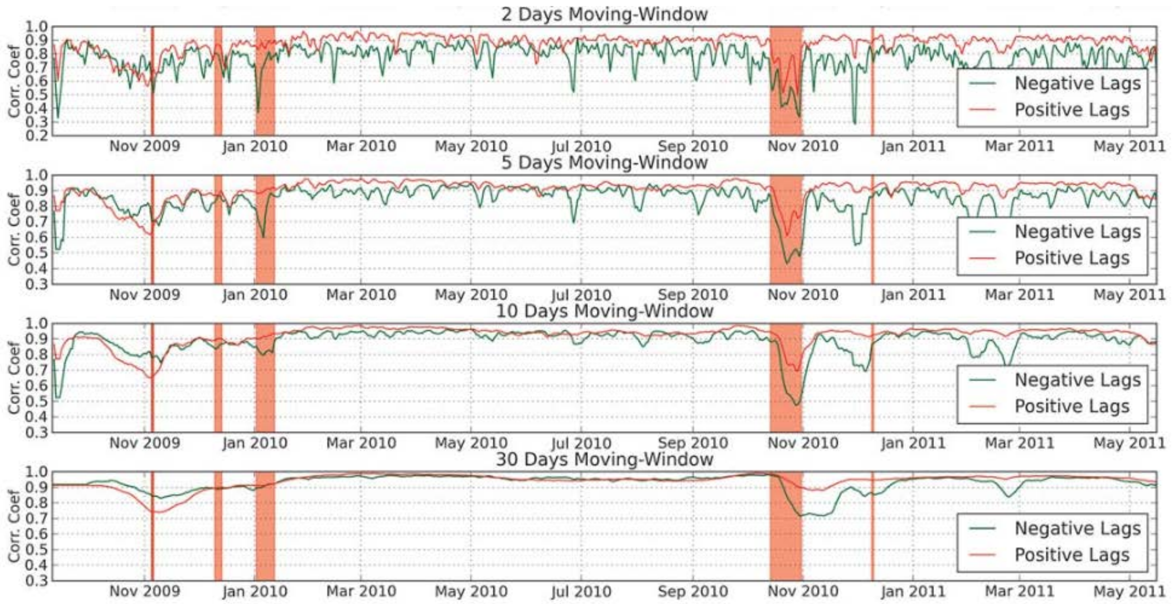
In the literature

Tomography examples



Liang and Langston, 2008 ; Poli et al., 2013 ; Brenguier et al., 2007 ; Mordret et al., 2013

Monitoring examples



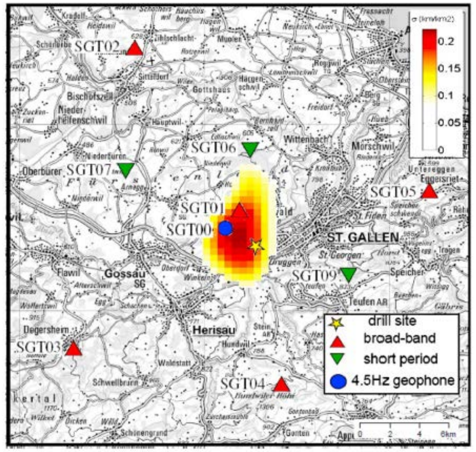
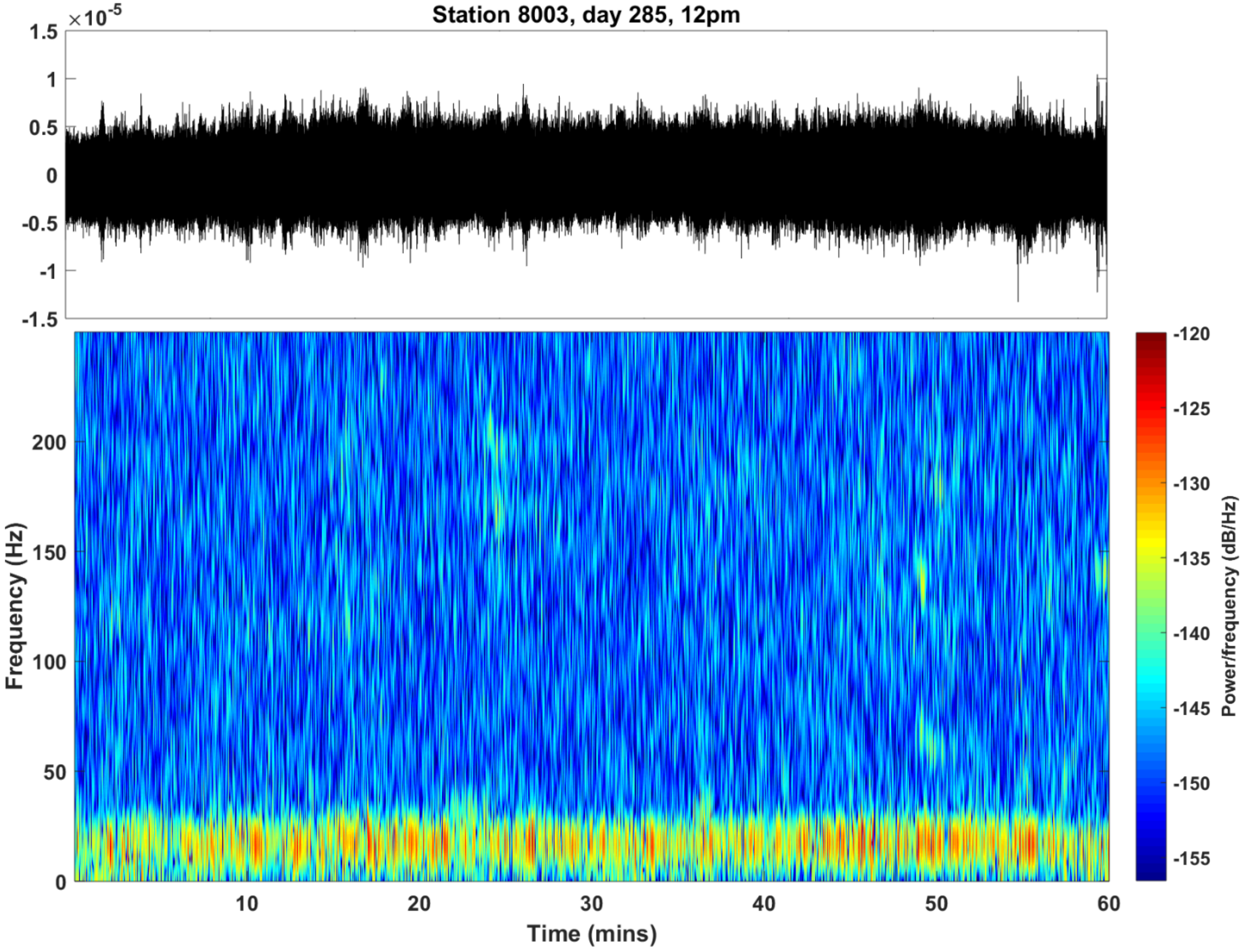


Figure 9. Scattering cross-section density changes derived by least squares inversion averaged over July 2013. The observed changes are around the injection well, indicating a causal relationship with the activities at the well.

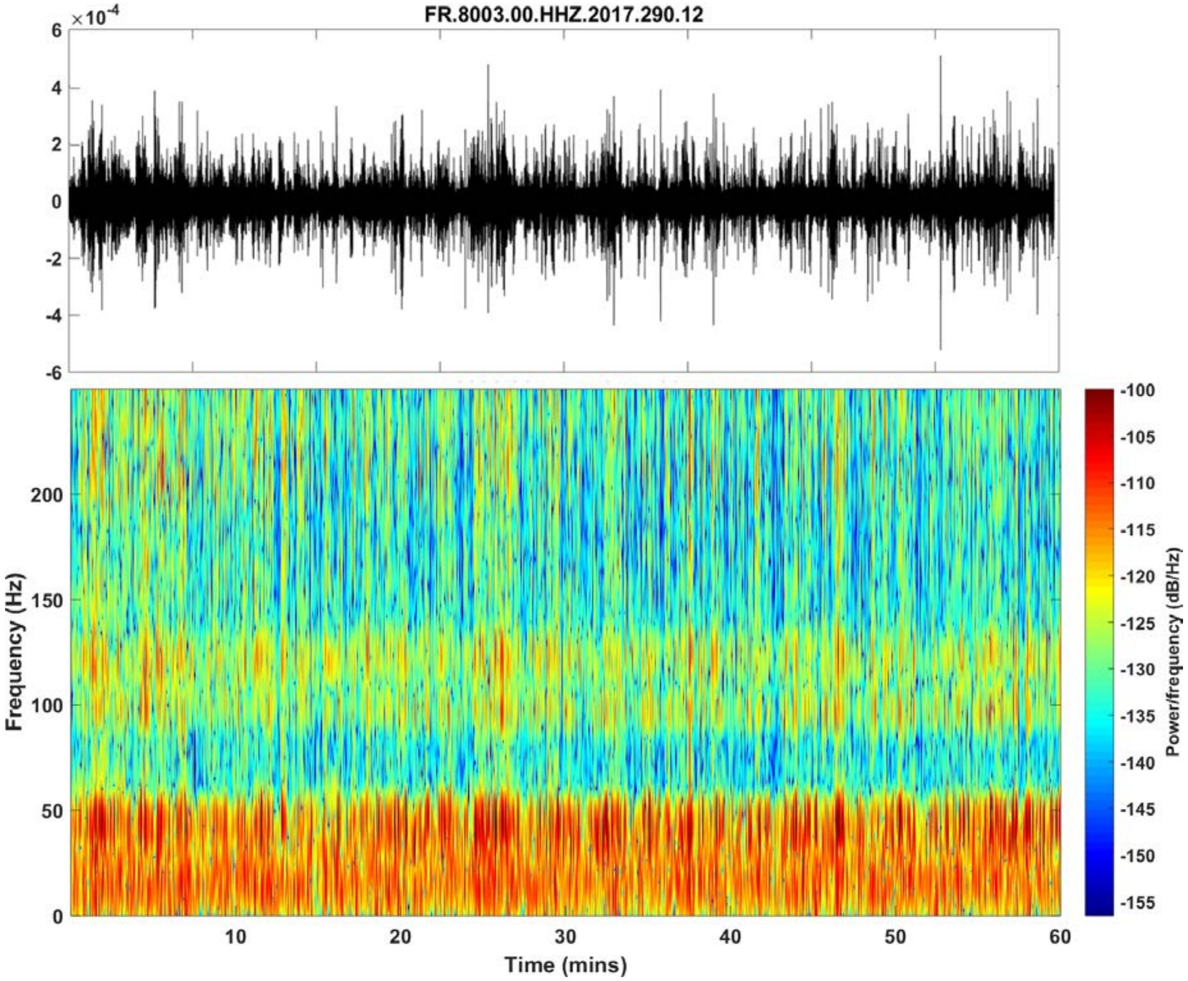
Lecocq et al., 2014, Obermann et al., 2015

Raw traces - Noise

1hour "quiet"

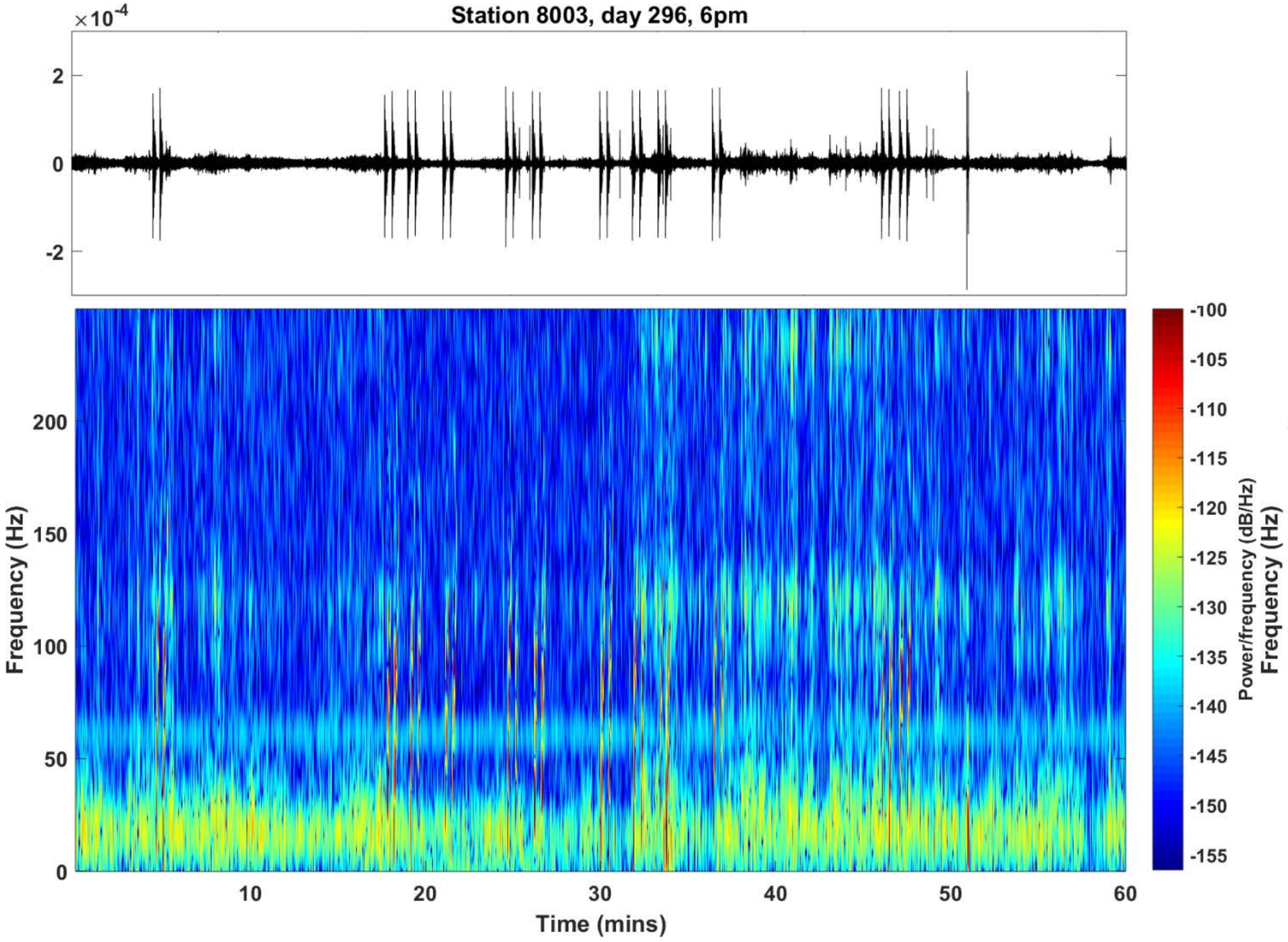


1hour windy

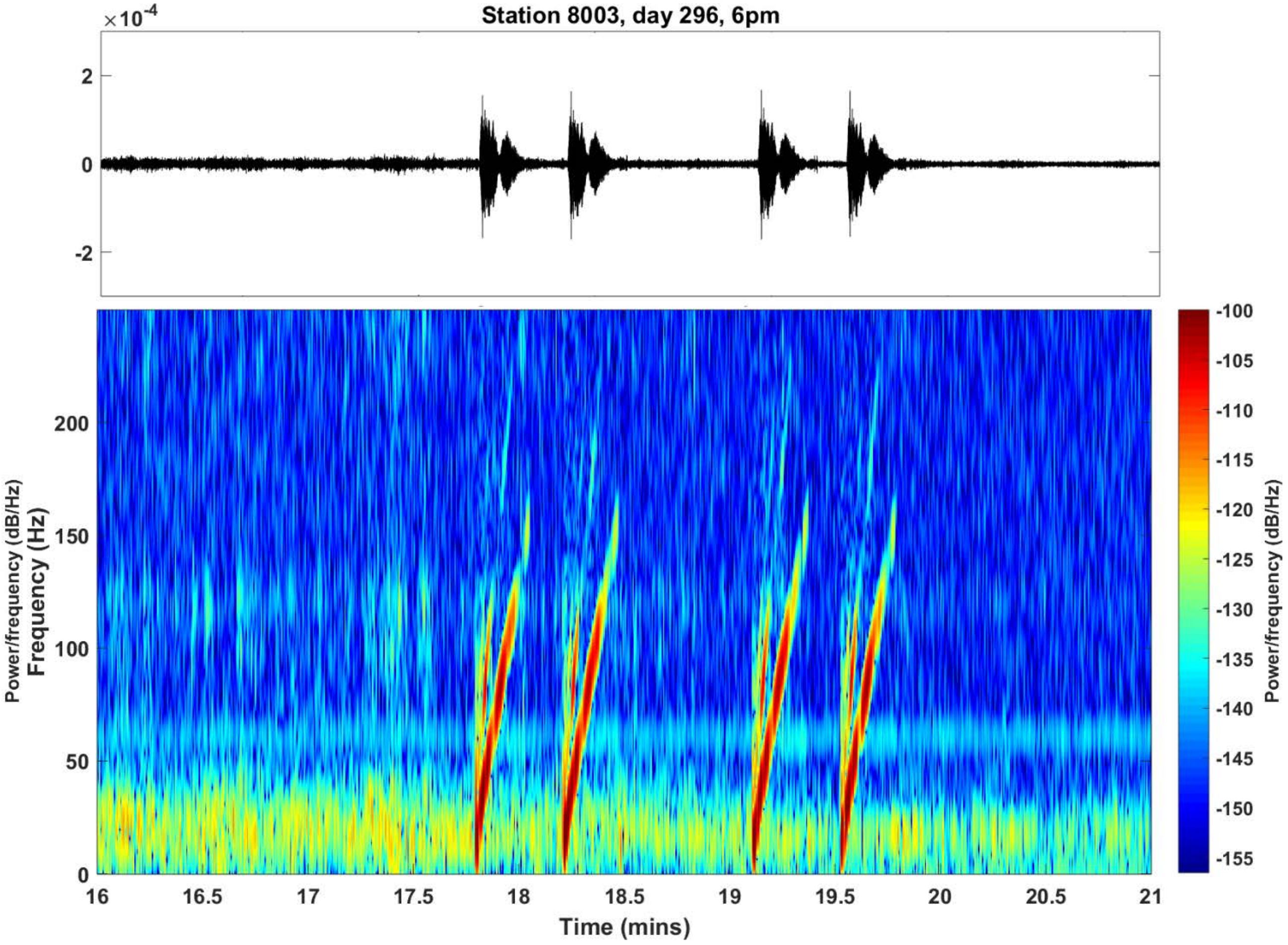


Raw traces – Active seismic survey

1hour

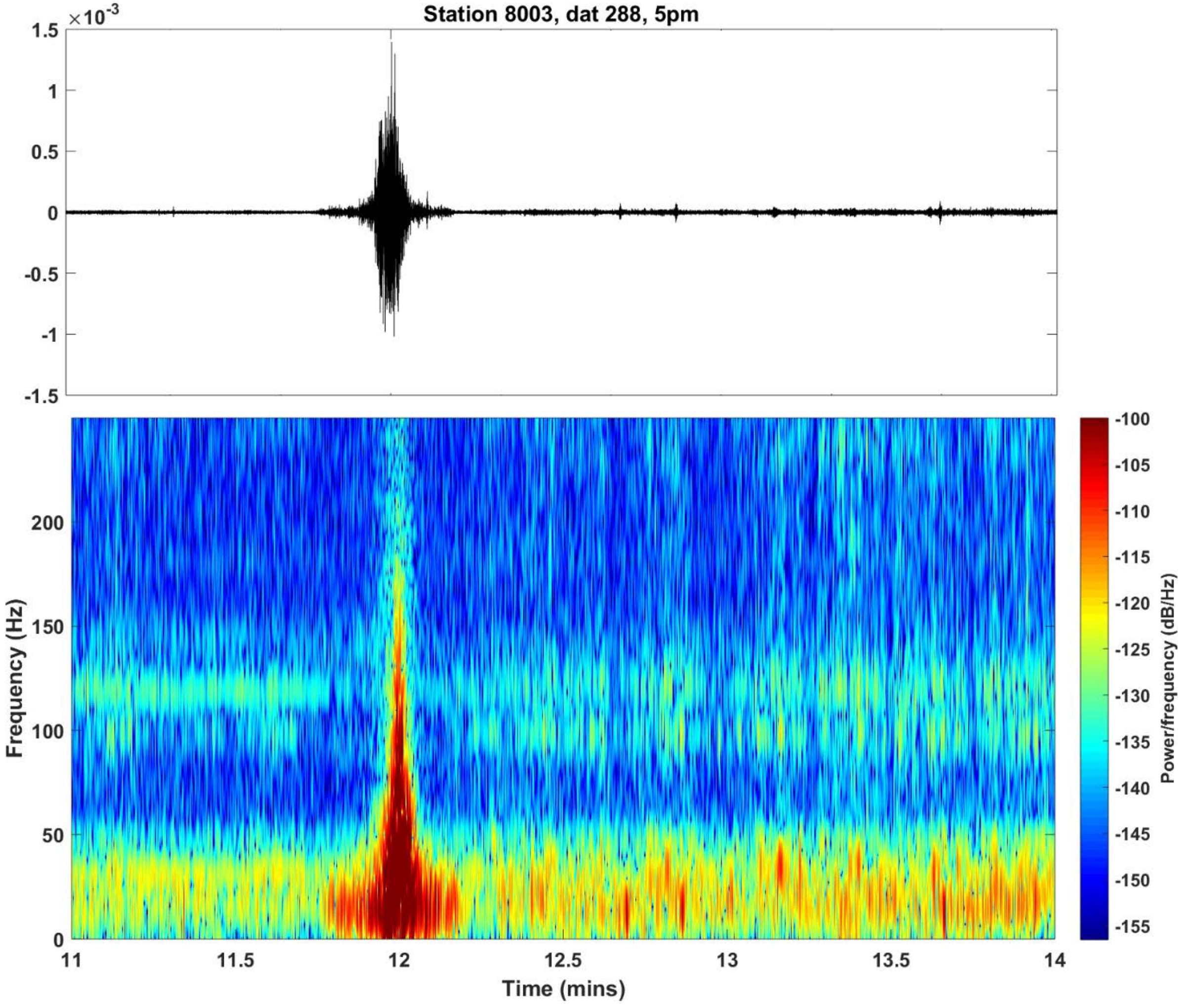


5min

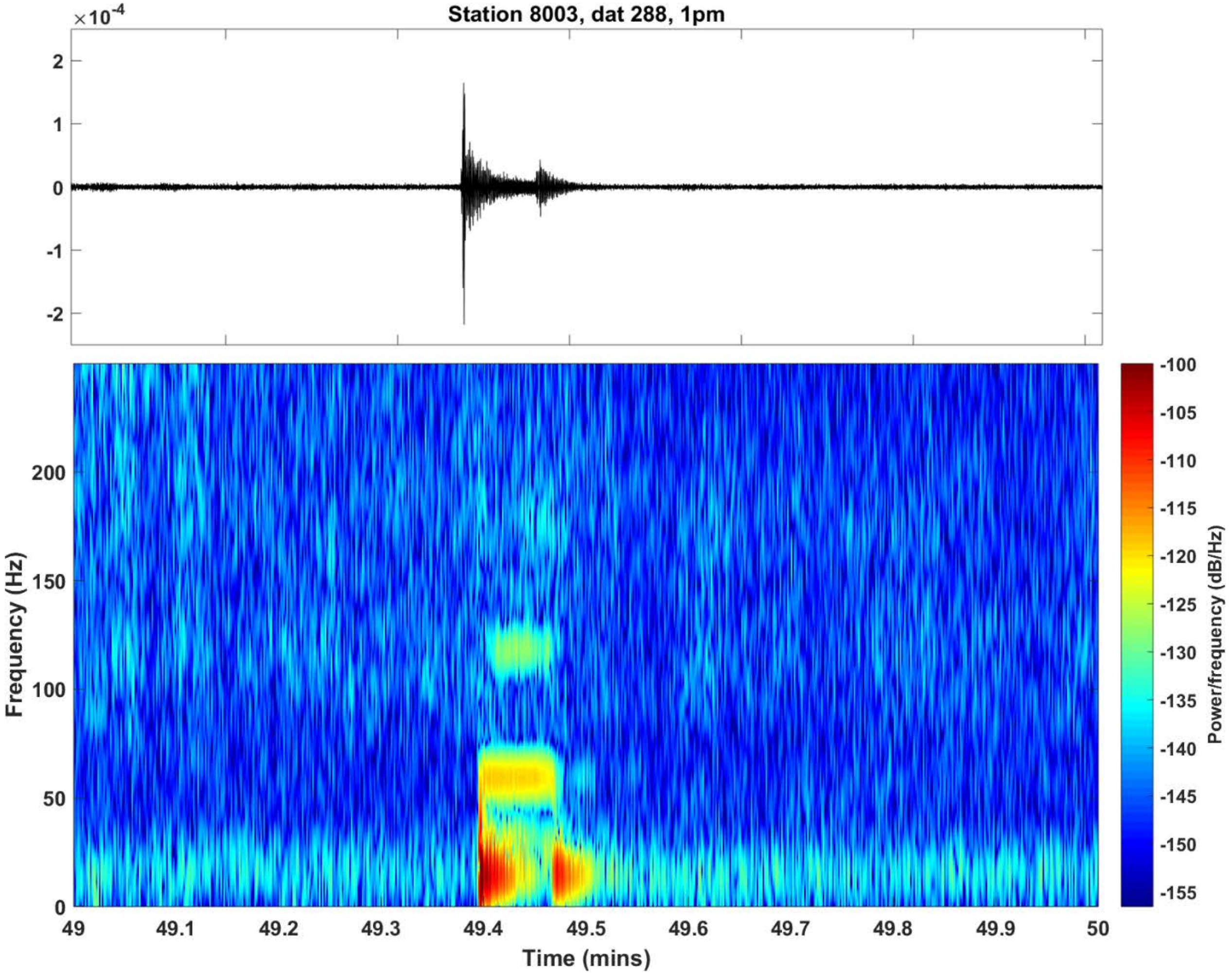


Raw traces – Punctual signals

3min

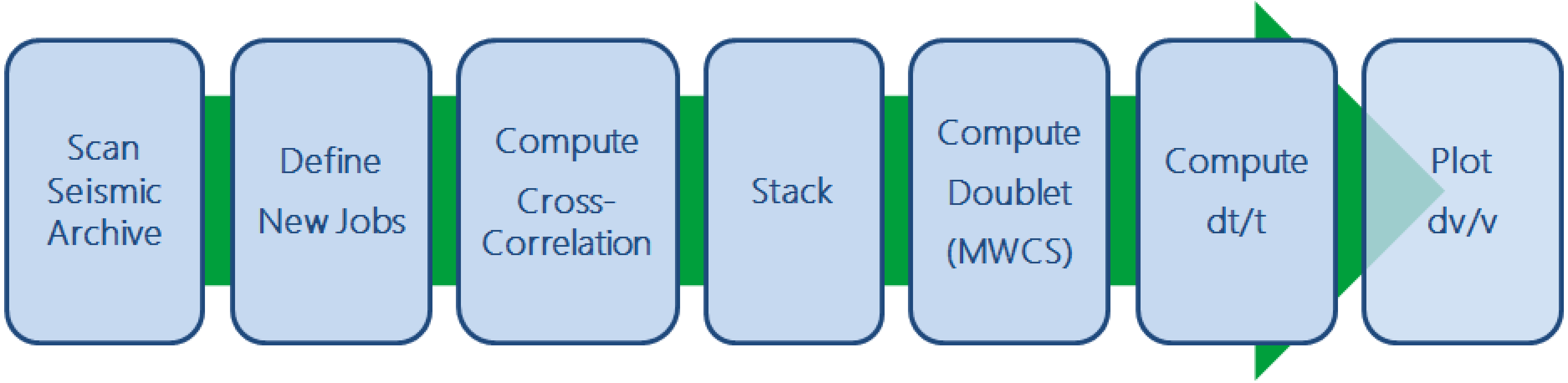


1min



MSNoise (Lecocq et al., 2014)

Monitoring using Seismic Noise, Python package

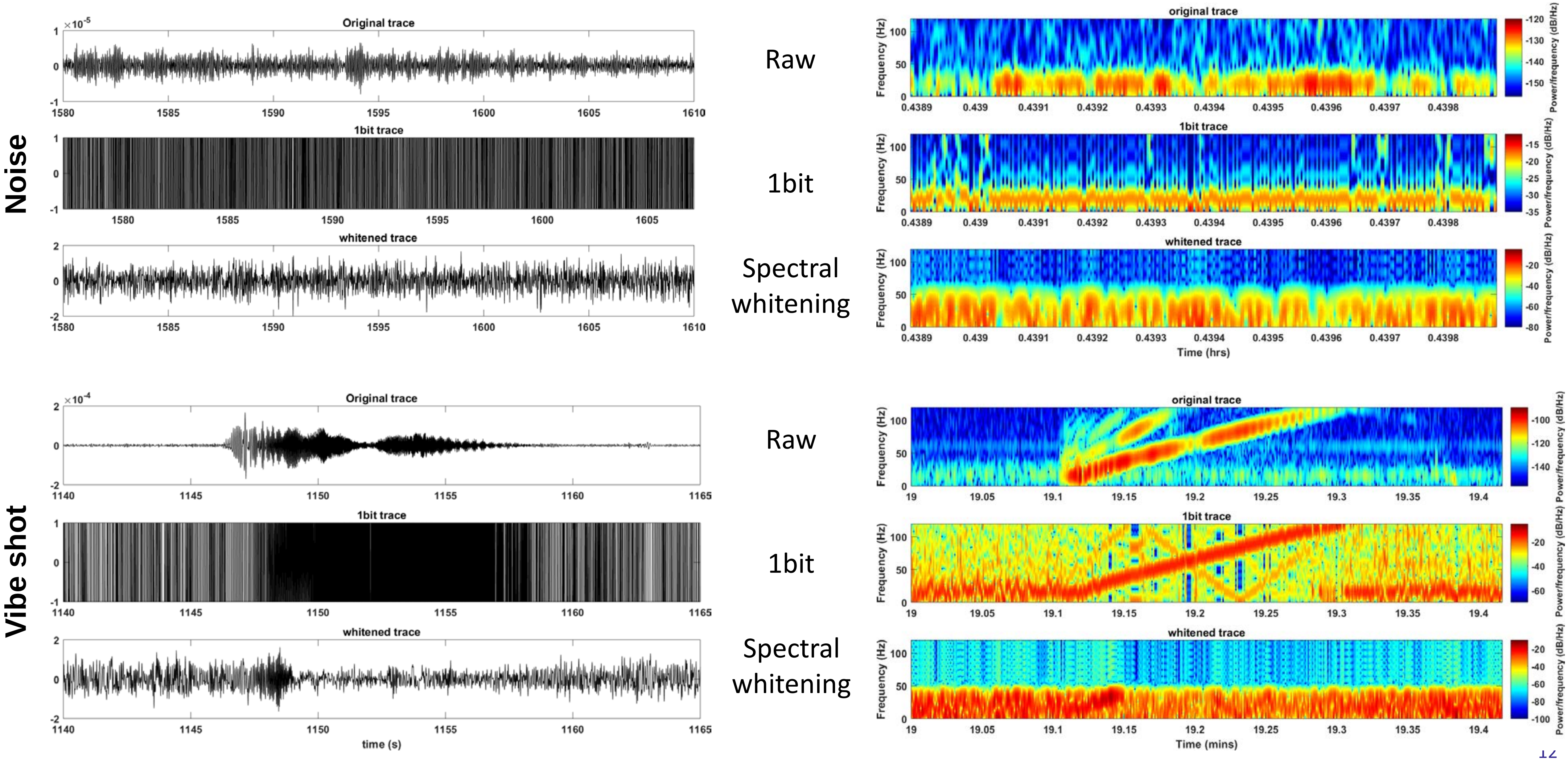


- ❑ Usual processing implemented (filtering, 1-bit, spectral whitening…)
- ❑ Moving-Window Cross-Spectral method (also know as doublets technique) to study the relative dephasing between Moving-Window stacks ("Current") and a Reference (Poupinet et al, 1984, Clarke et al., 2011)
- ❑ Parallel processing, can easily add your own plugins

Processing used in this study:

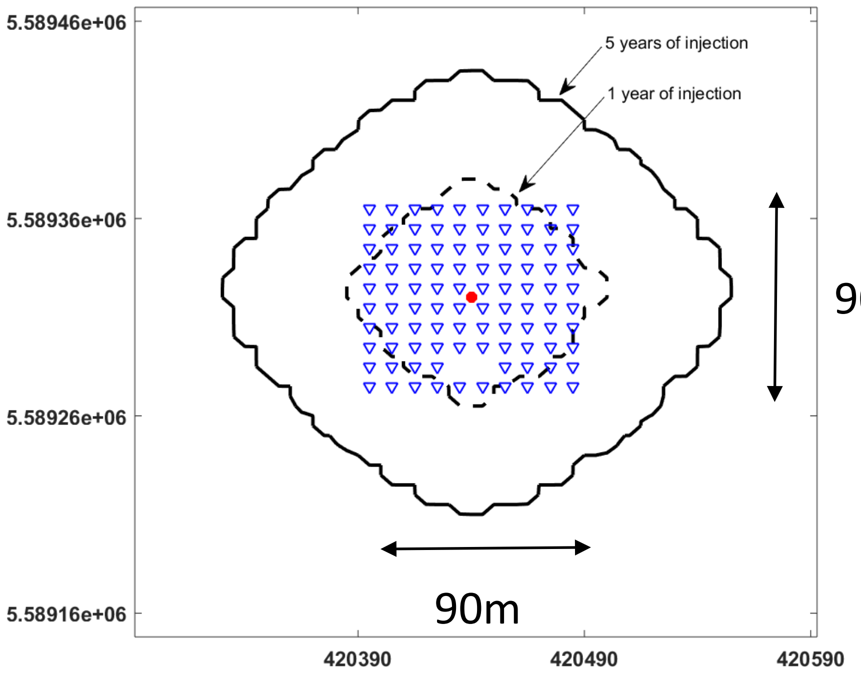
- ❑ Demean
- ❑ Detrend
- ❑ Down sampling from 1000 to 200Hz
- ❑ Time-domain normalization: 1bit
- ❑ Frequency-domain normalization: spectral whitening [0.5- 30]Hz

Processing – 1bit & spectral whitening



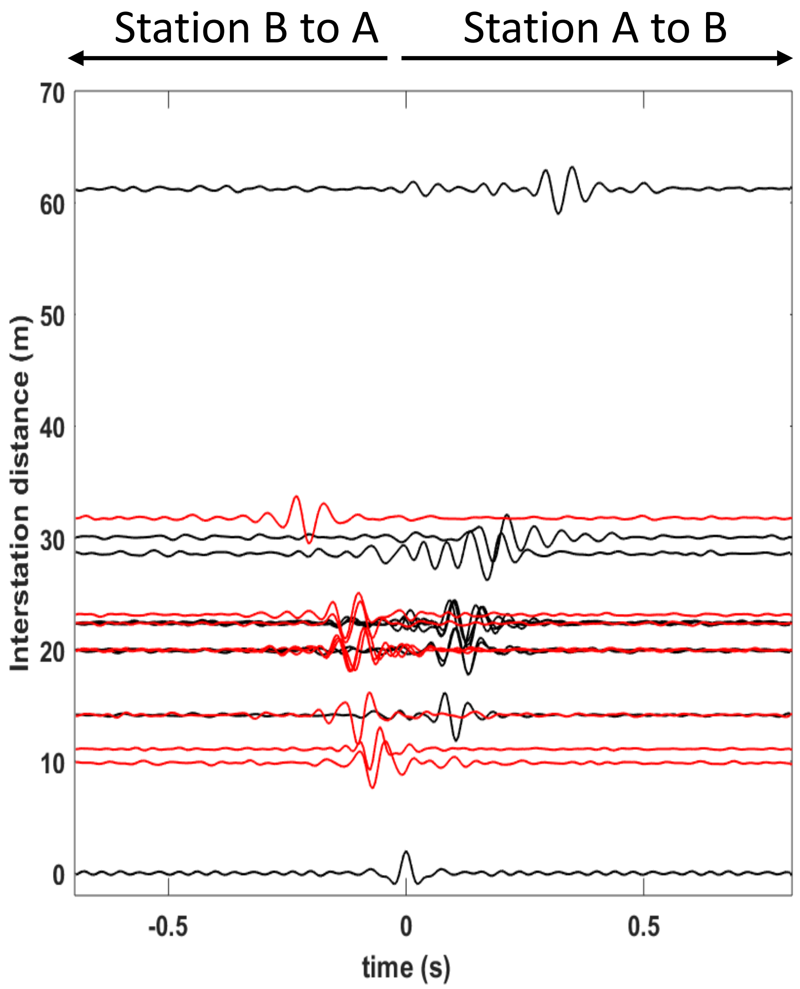
Correlations

October 2017 dataset

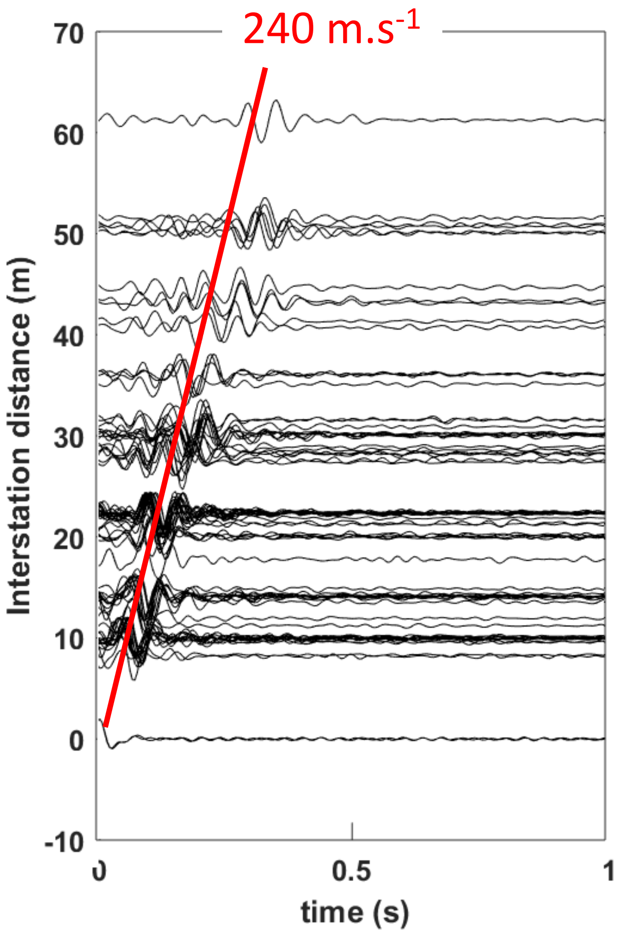


98 stations => 4753 pairs of stations

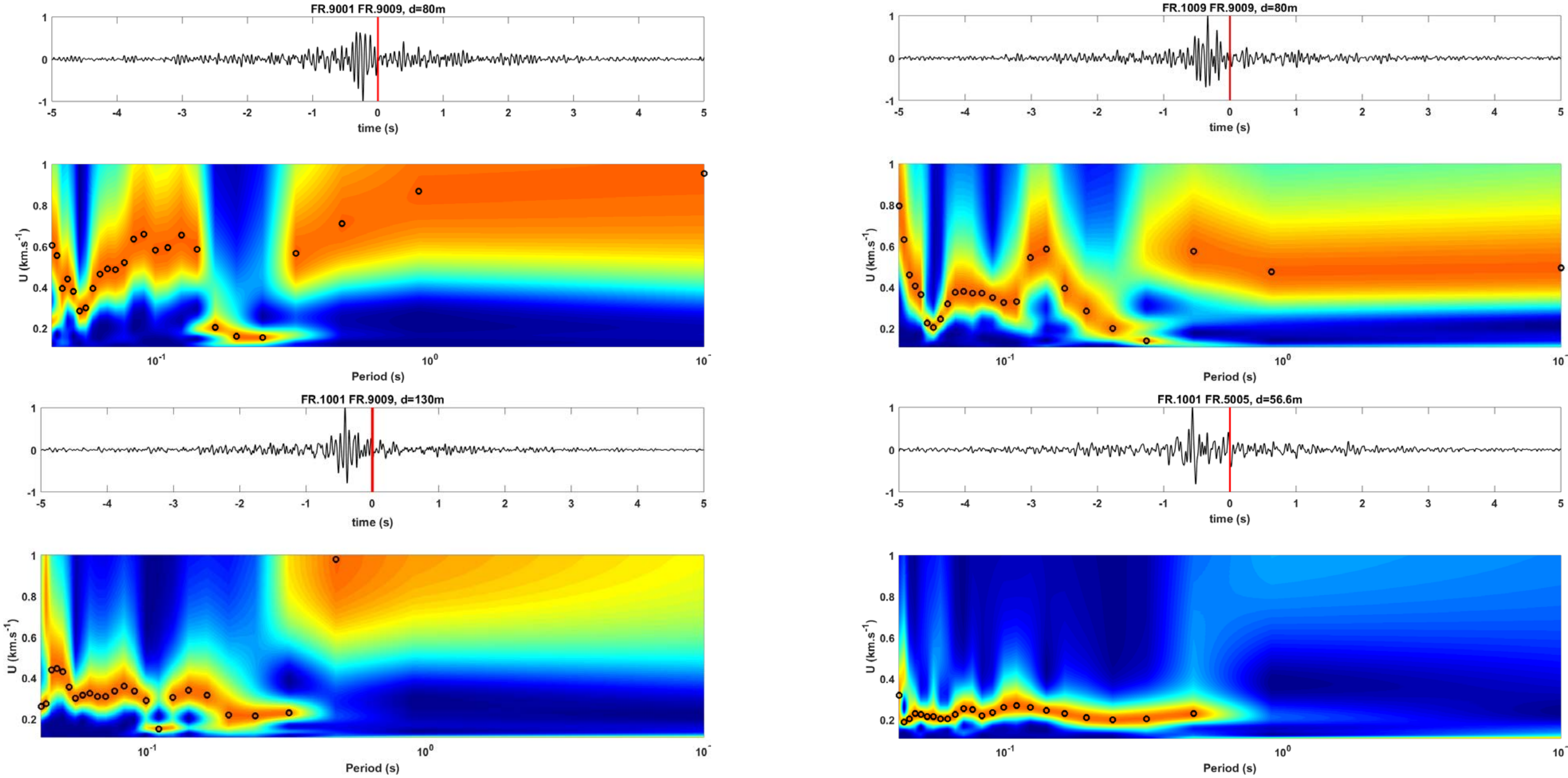
Noise directivity, SNR > 14



14 daily correlation stacked
SNR > 8

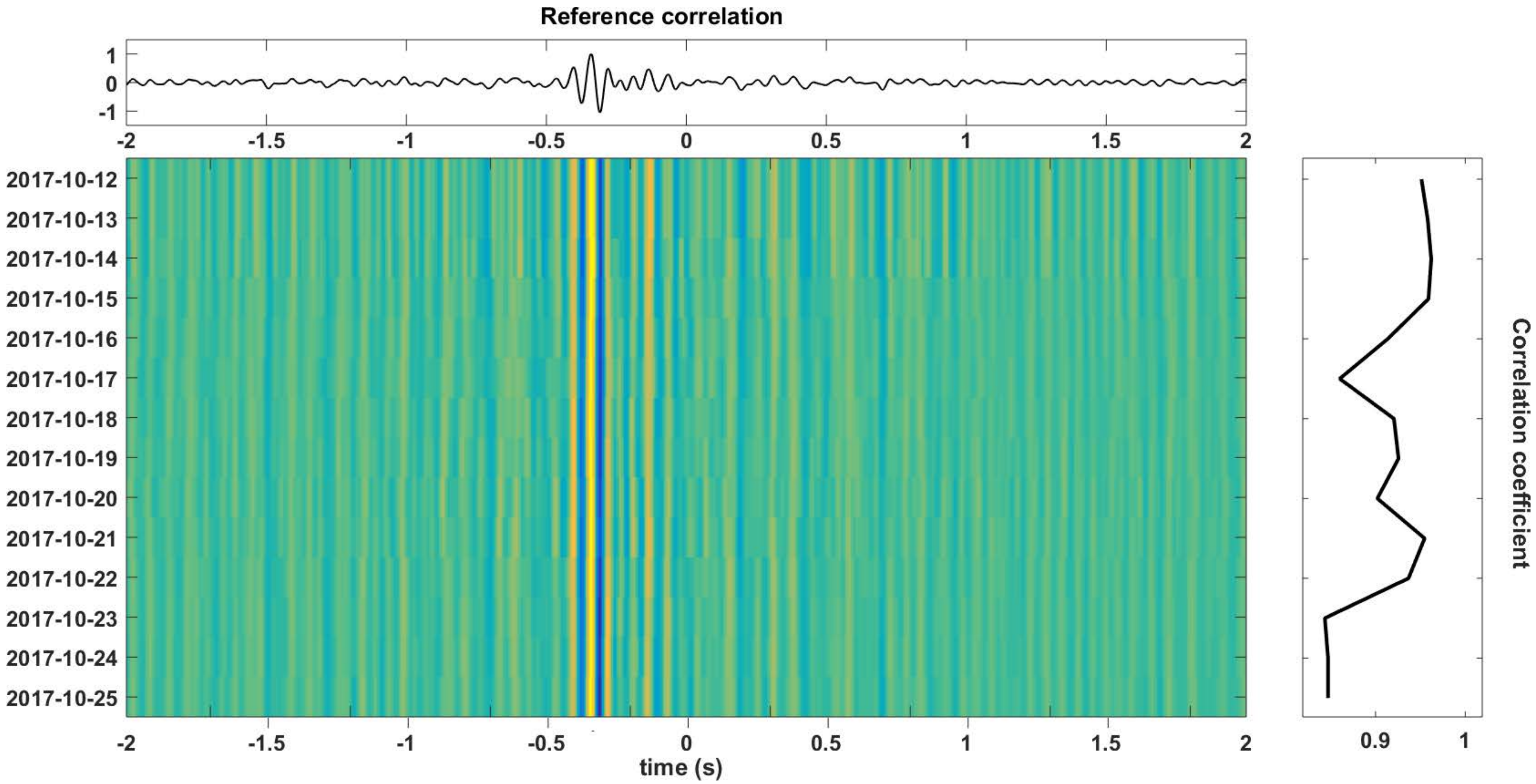


Group velocity dispersion curves – Frequency Time Analysis

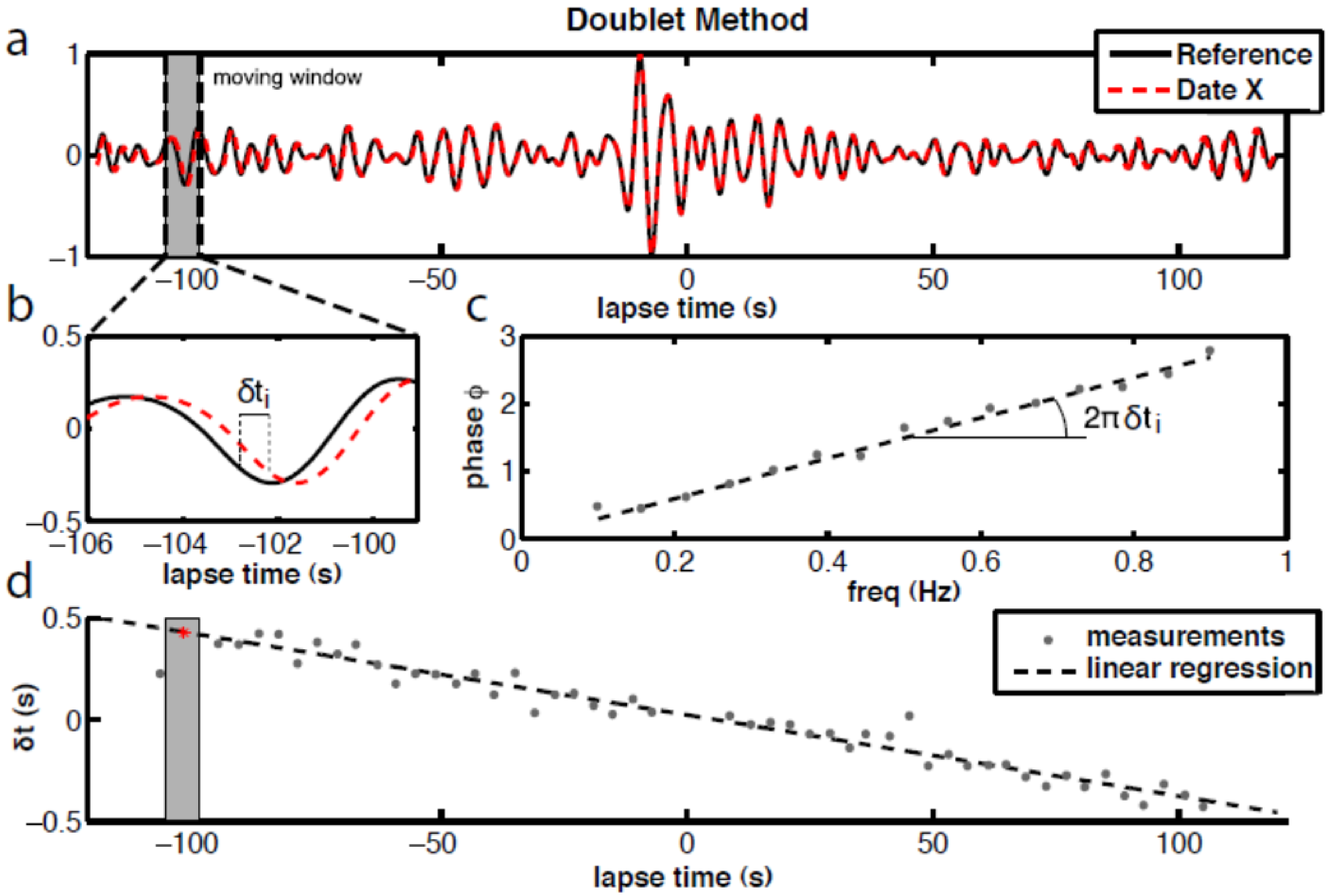


Application for monitoring

Good stability in the daily correlations



MWCS method (or doublet method, *Poupinet et al., 1984, Clarke et al. 2011*)



Hadziioannou (2011)

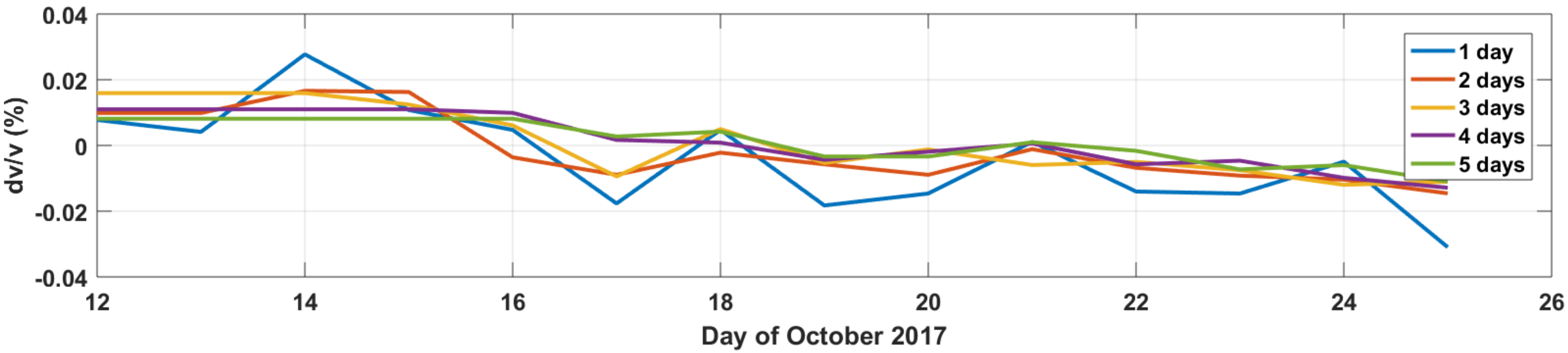
Shift between reference correlation and current correlation

δt_i computed in frequency domain

$$\delta v / v = - \delta t / t$$

Application for monitoring – MWCS method

Reference correlation: 14 days stacked, current correlation : 1 to 5 days stacked



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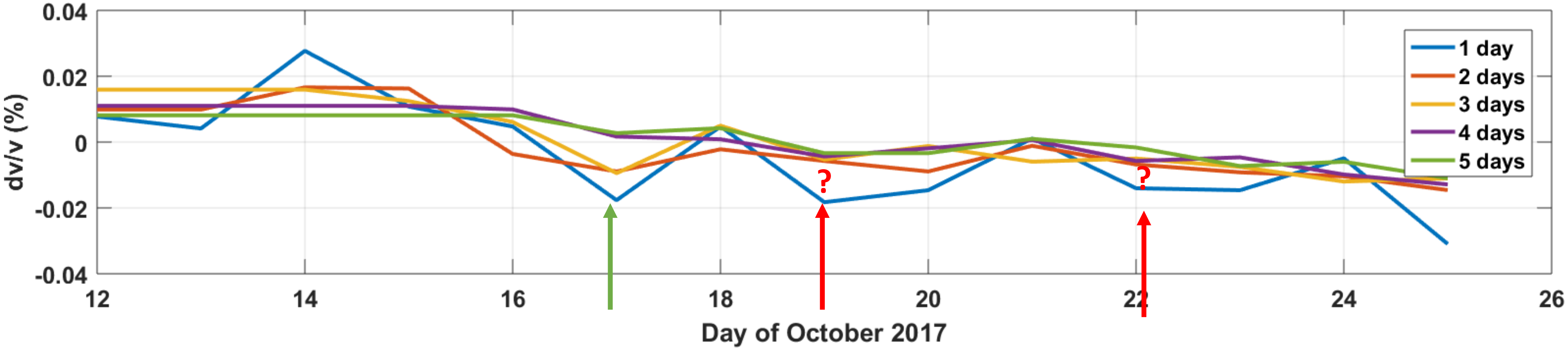

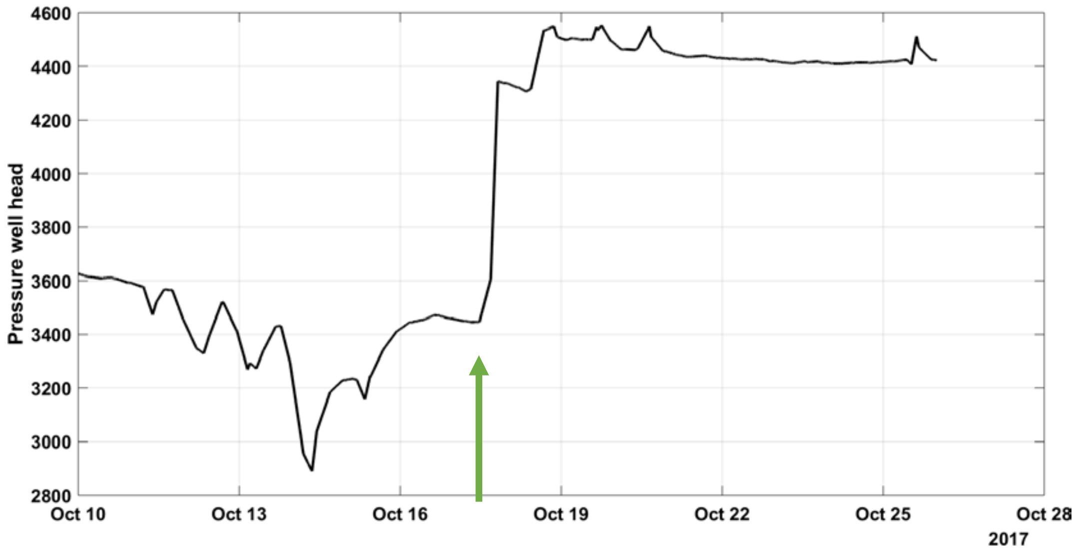

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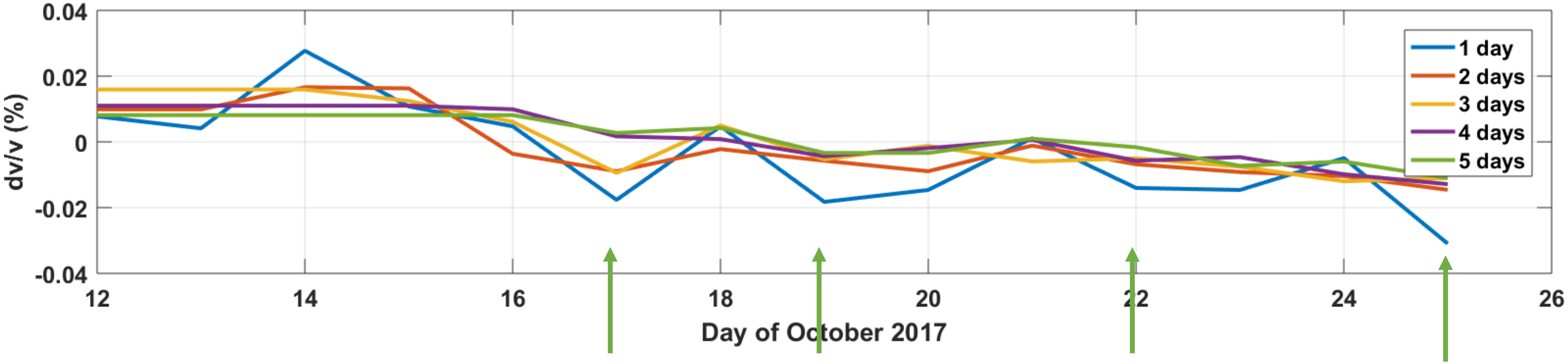

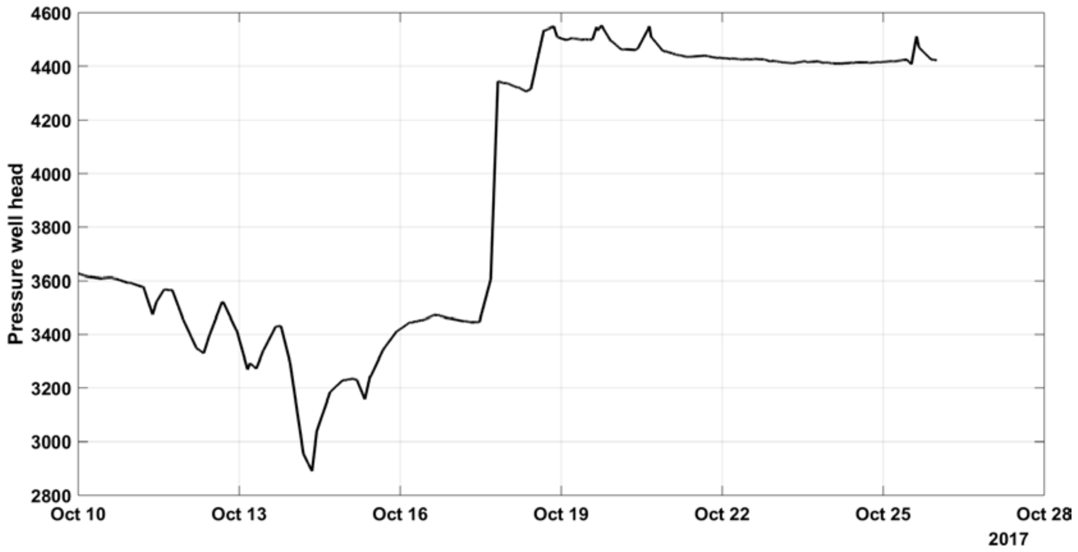

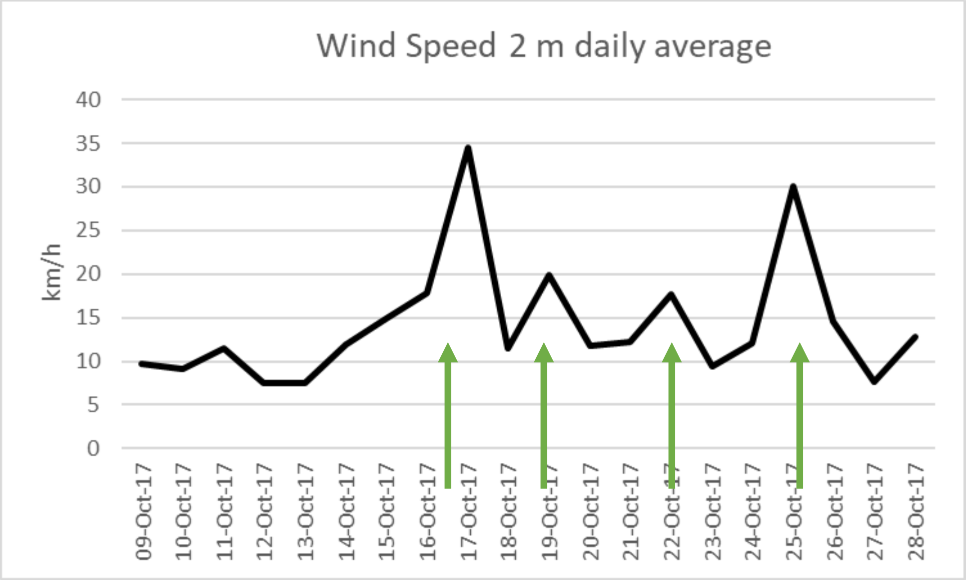

Or temperature effects ? Or groundwater level effects ? Or …

Conclusions & Future work

Conclusions

- Pros: passive technique, little impact on environment
- Cons: huge volume of raw data (15 days of continuous data, 98 stations => 1.3To)
- Coherent group velocity dispersion curves => application for tomography
- Stability in correlation waveform => feasibility of using them for monitoring

Future Work

- Tomography using October 2017 and February 2018
- Noise directivity using beamforming
- Investigate and understand the velocity variations we observe
- October 2018 dataset: detection of micro-fractures using match-field processing ?

Acknowledgments

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