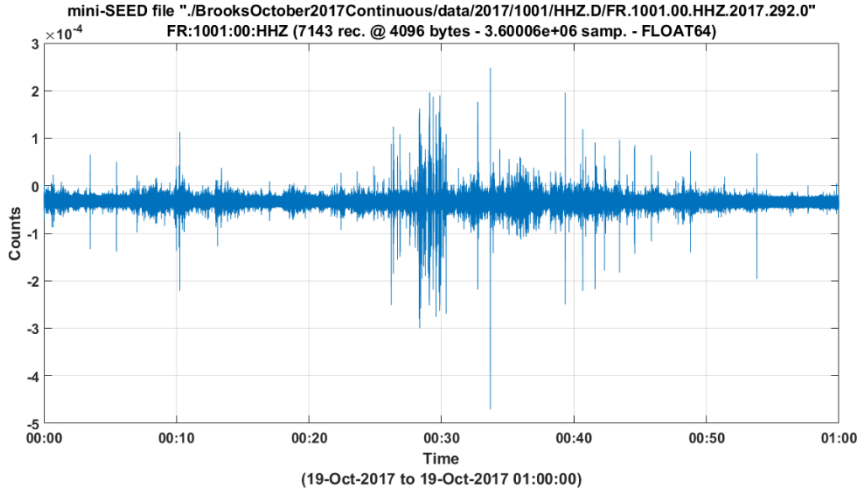
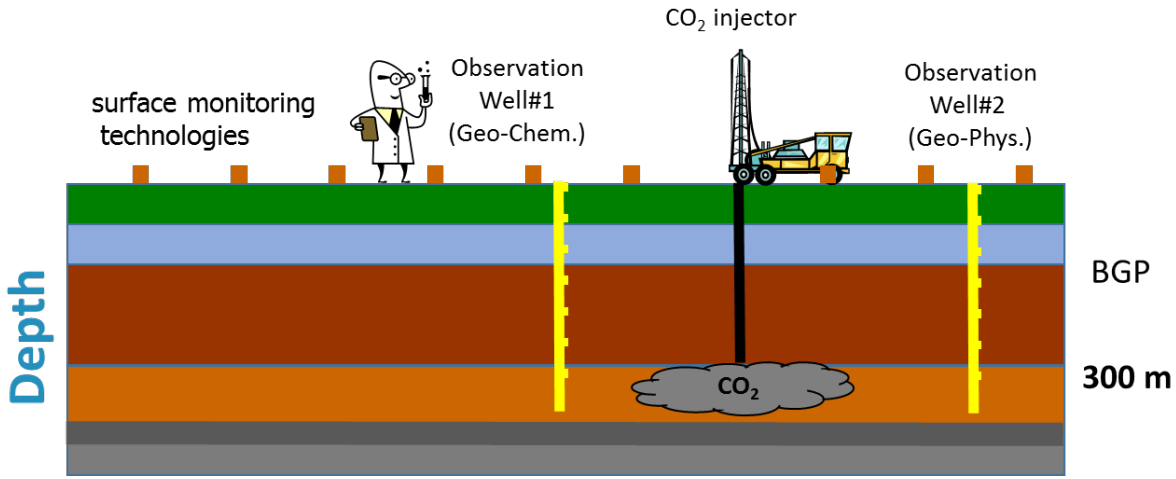
Working with continuous seismic data at the CaMI Field Research Station: some ideas to explore





CREWES Friday tech talk – February 2nd 2018

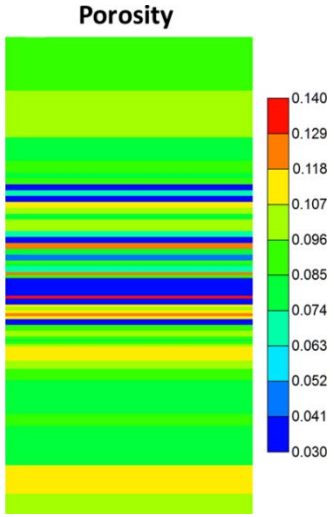
Summary – CREWES 2017 Annual Meeting

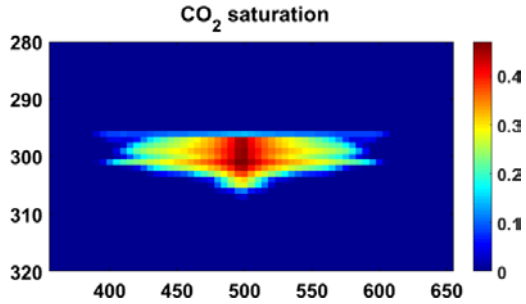
1) Geomodelling

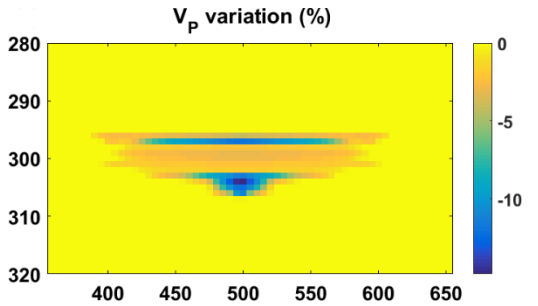
2) Fluid flow simulations

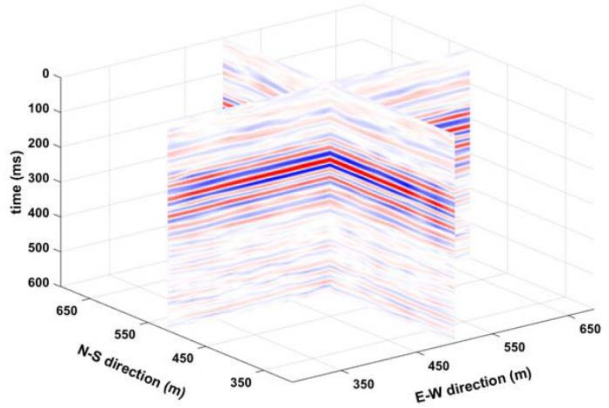
3) Fluid substitution

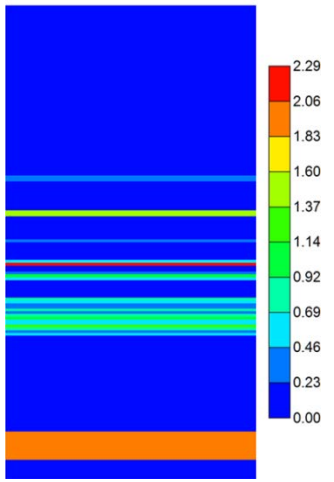
4) Seismic response simulation

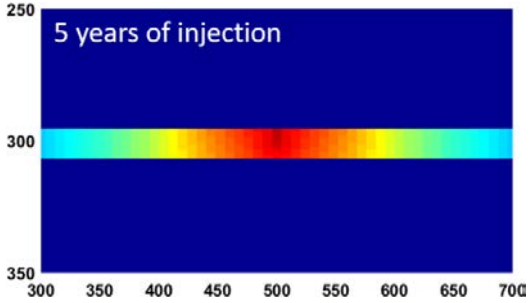


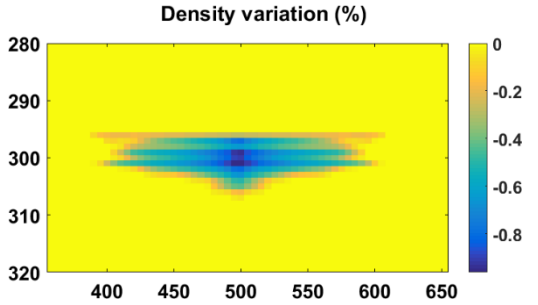


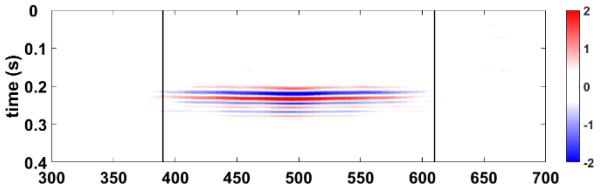












Conclusions & Future work – CREWES 2017 Annual Meeting

1) Geomodelling	2) Fluid flow simulation	3) Fluid substitution	4) Seismic response simulation

ASSUMPTIONS

Assumption on vertical permeability	Assumption on the maximum bottom-hole pressure	Assumption on the Saturation behavior	Assumption on perfect survey repeatability

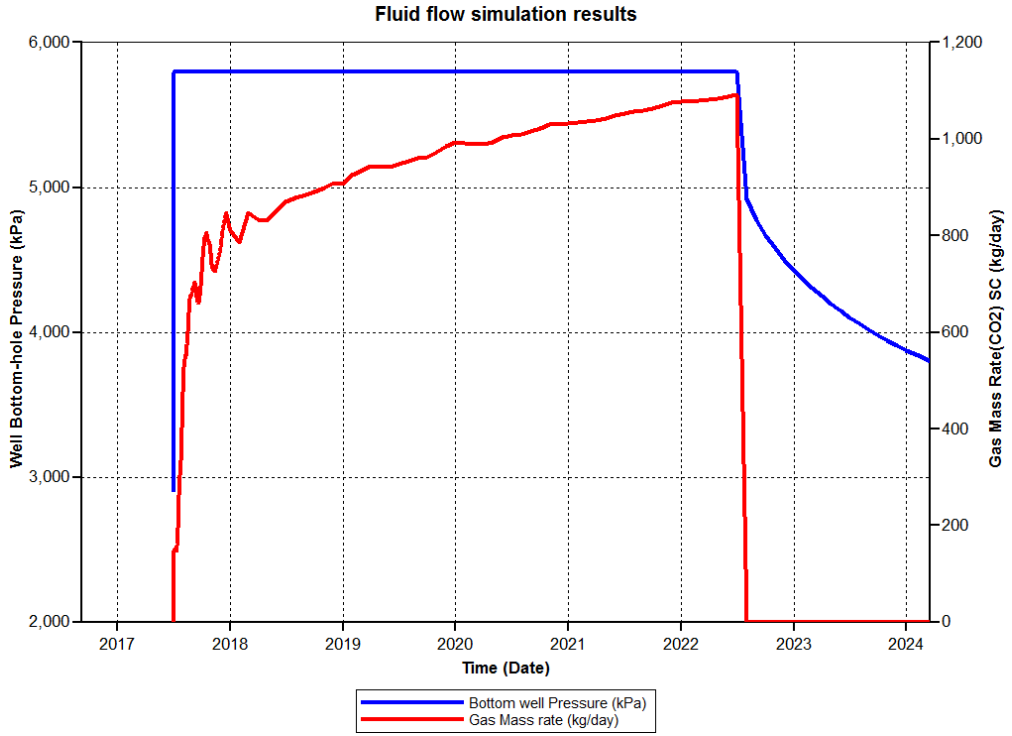
WHAT WE CAN DO

History match and updating geostatic models	Better estimation with pressure data from injection on field	Lab tests to better understand saturation behavior	Estimate non-repeatability using 2 datasets acquired on field

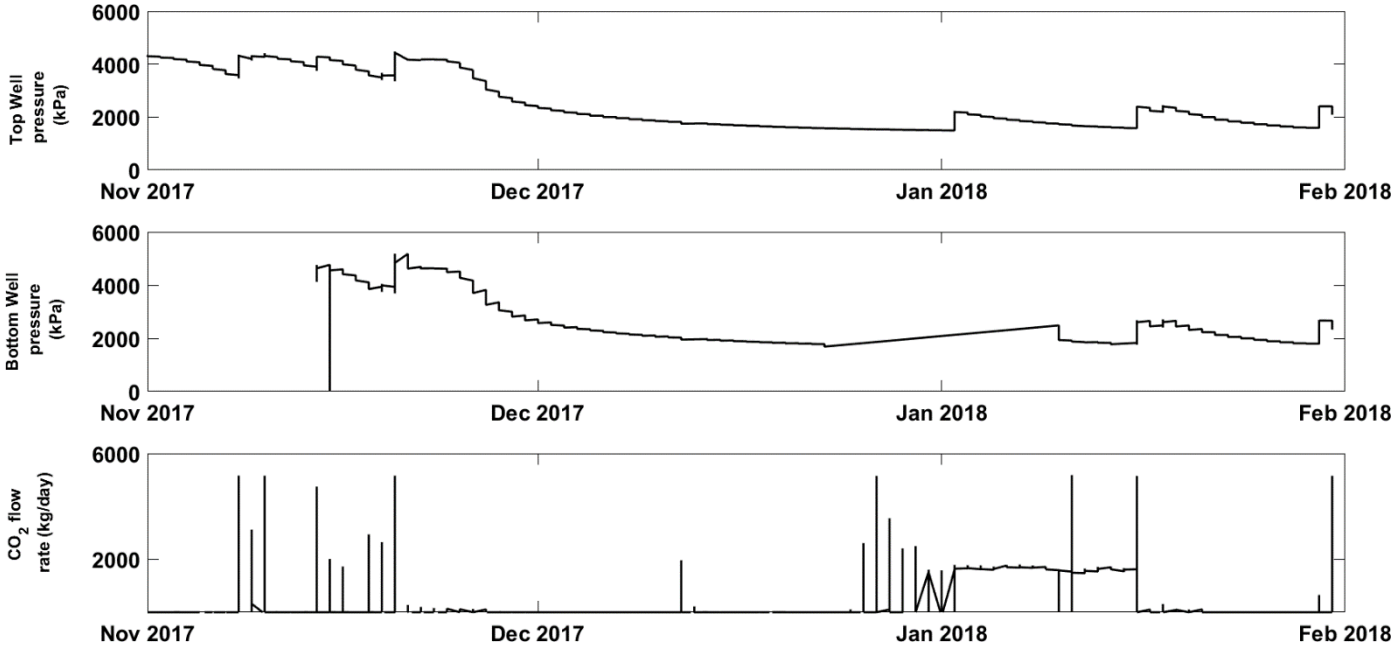
Geostatic models update to fit to actual pressure & flow data

Simulation results

Layer-cake geomodel which is function of porosity, vertical and horizontal permeabilities



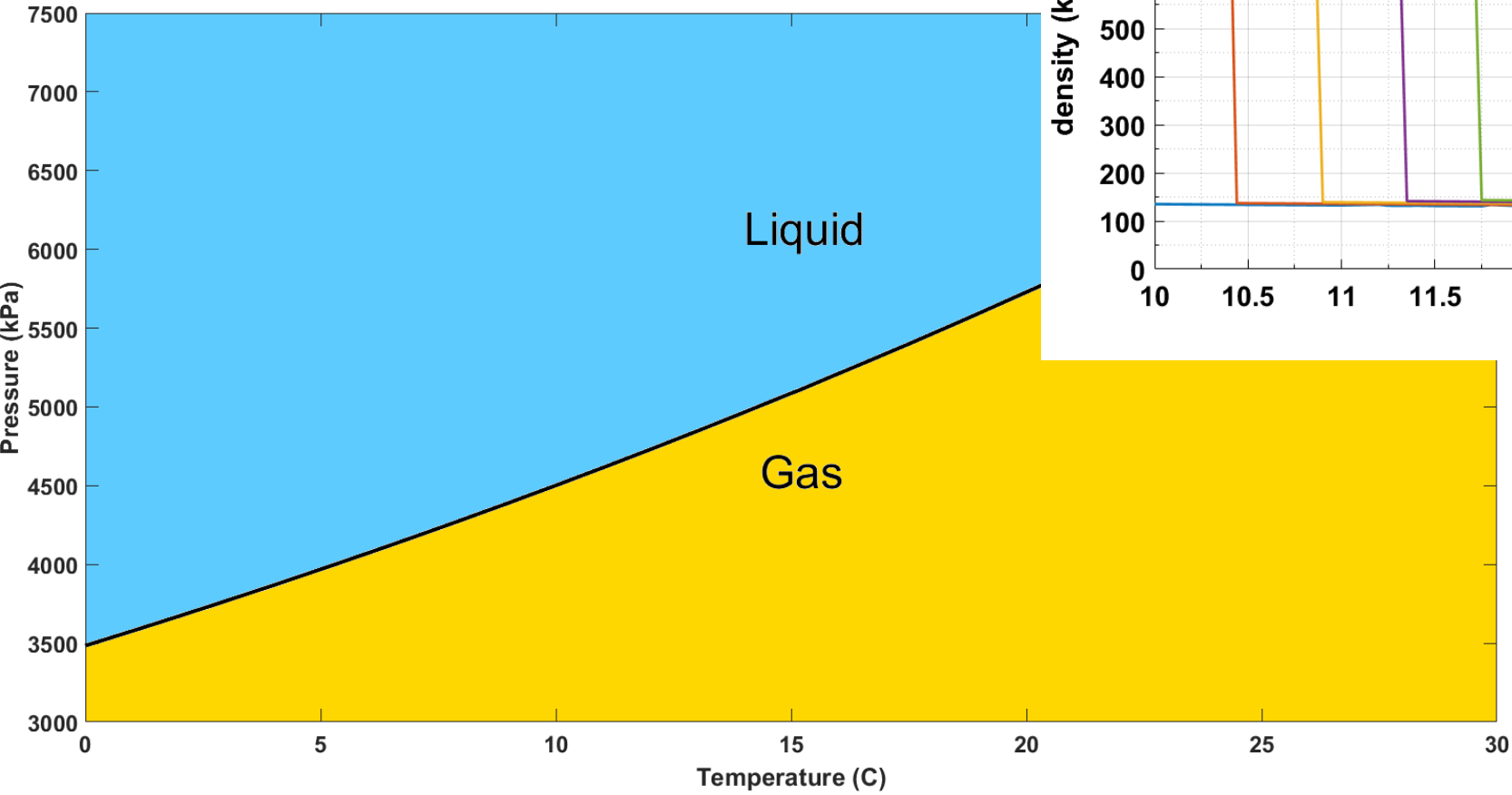
Field data

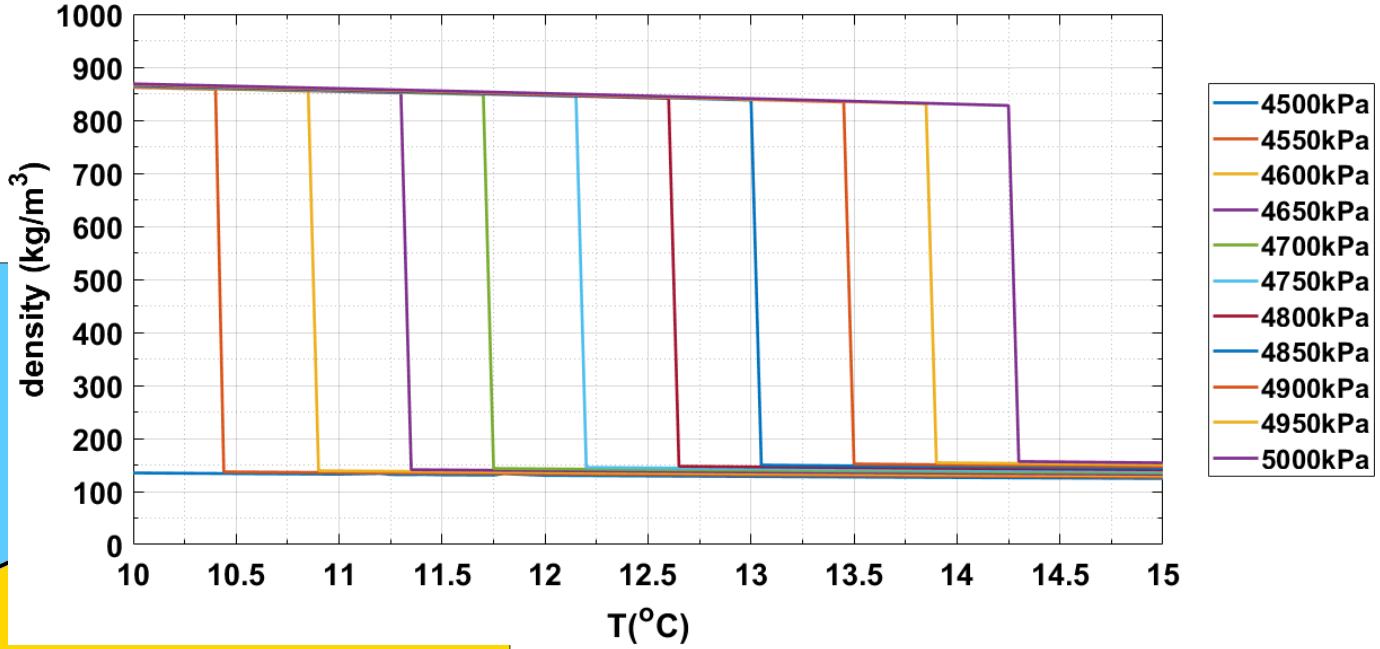


History match and updating geostatic models

Better estimation with pressure data from injection on field

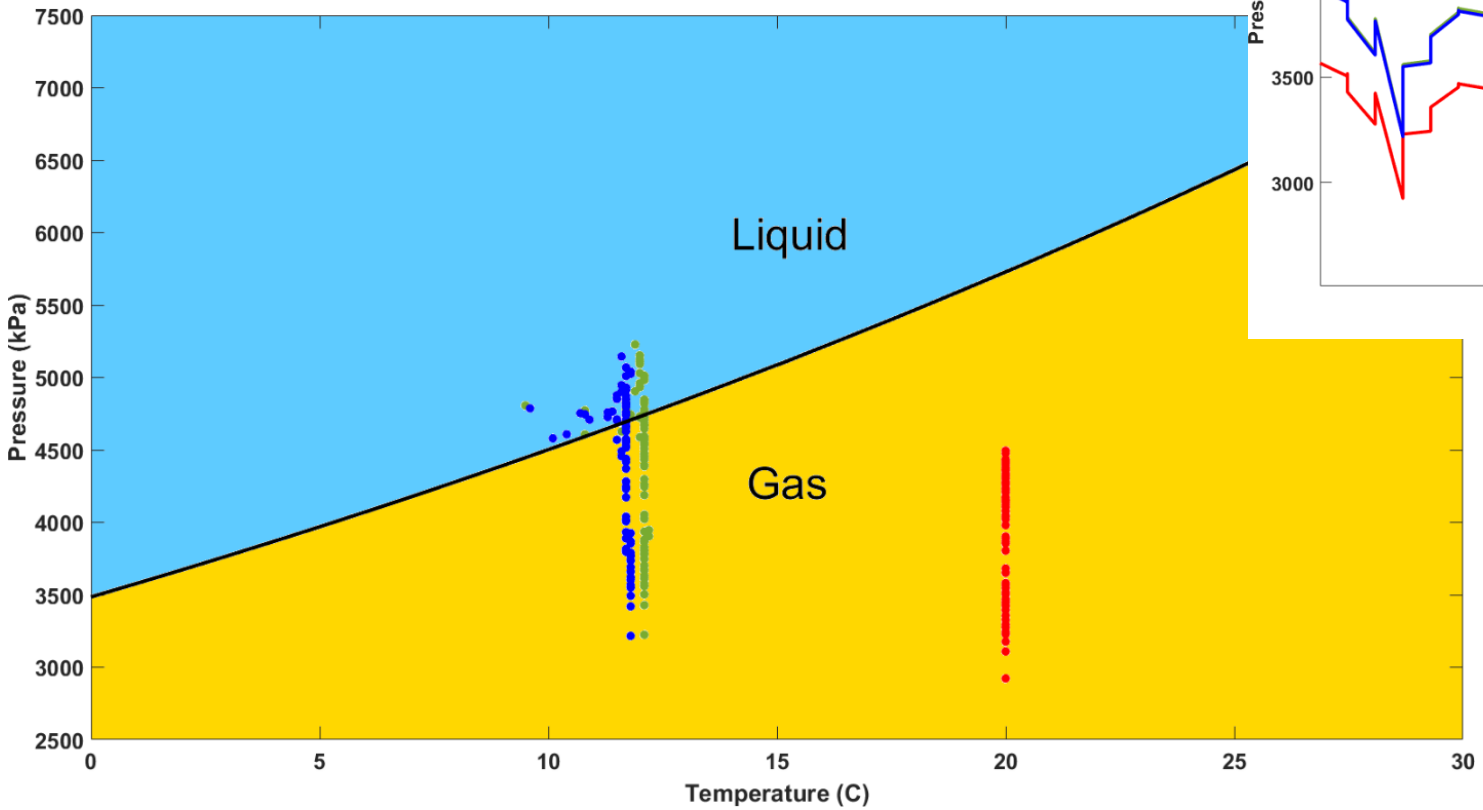
Pressure – temperature conditions at the CaMI.FRS

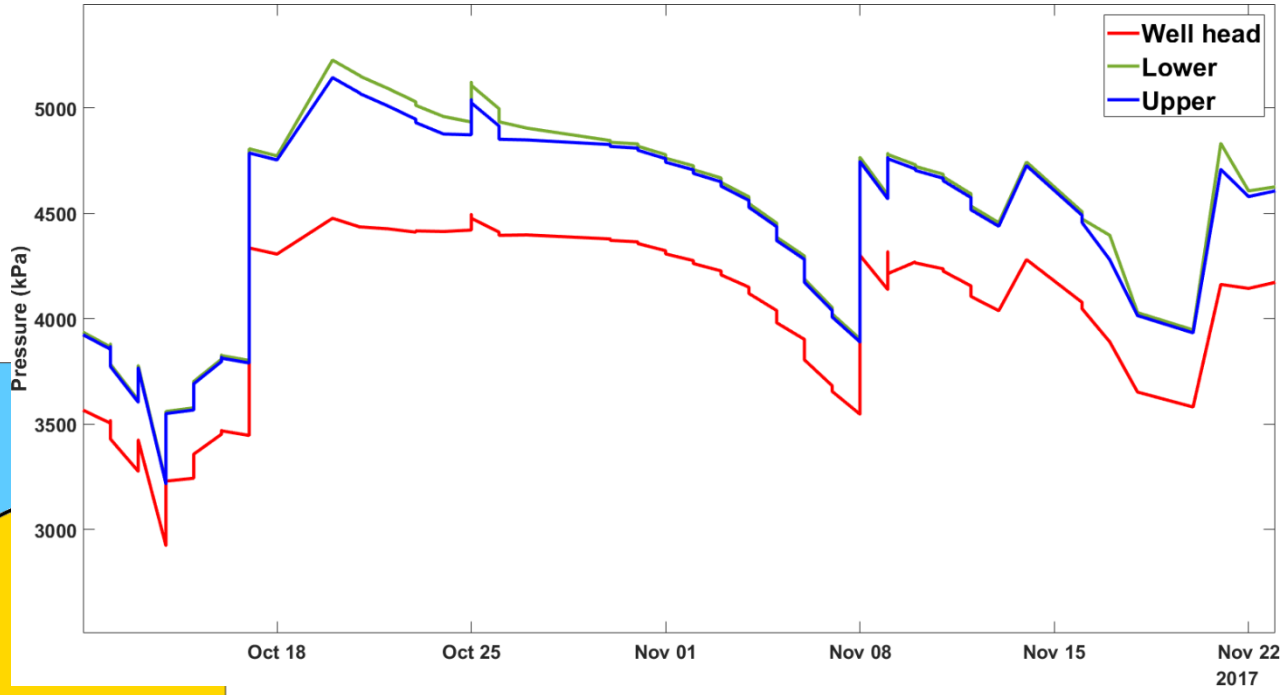




Pressure – temperature conditions at the CaMI.FRS

If the CO2 is always injected in gaseous phase,
It can become liquid at the bottom of the well





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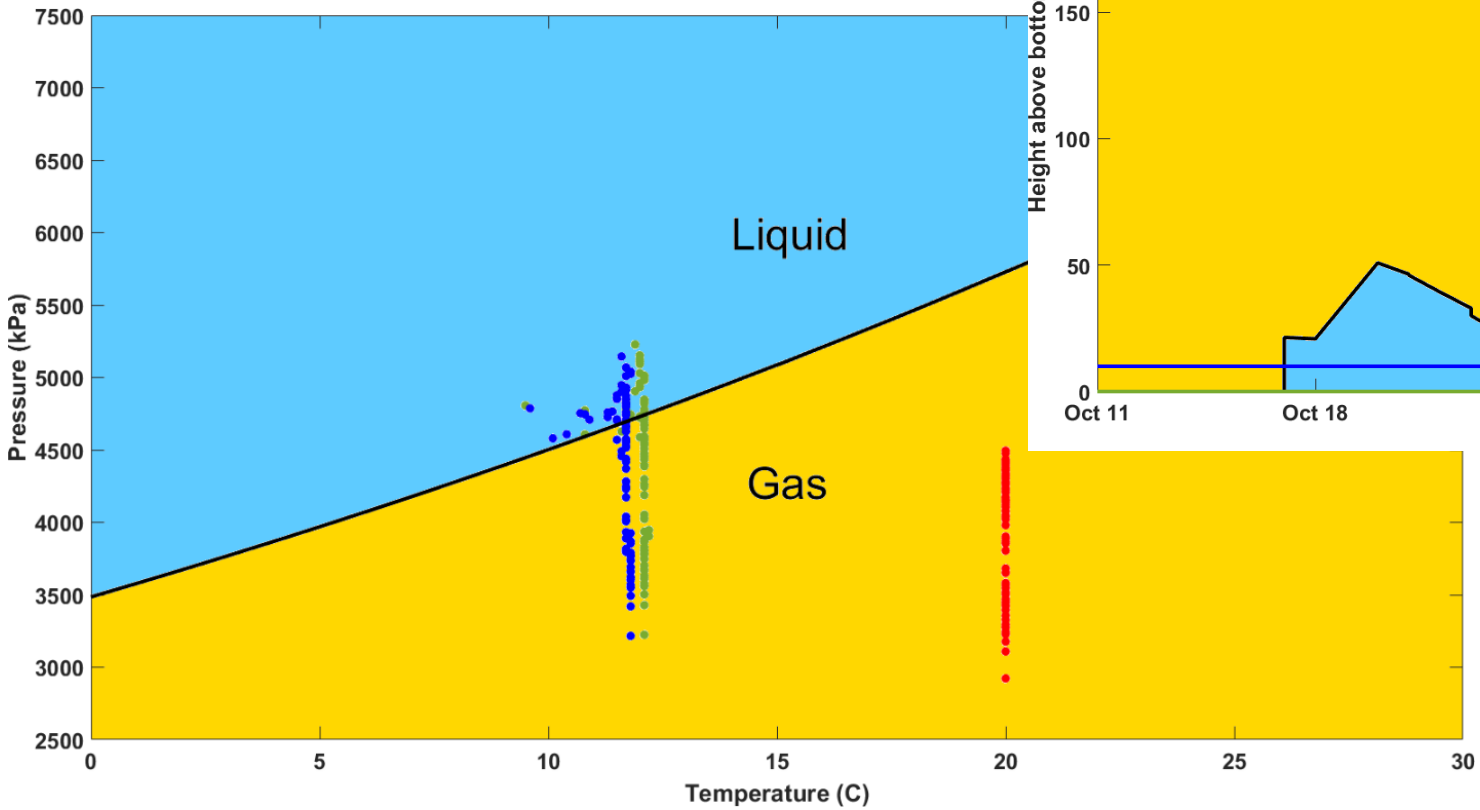

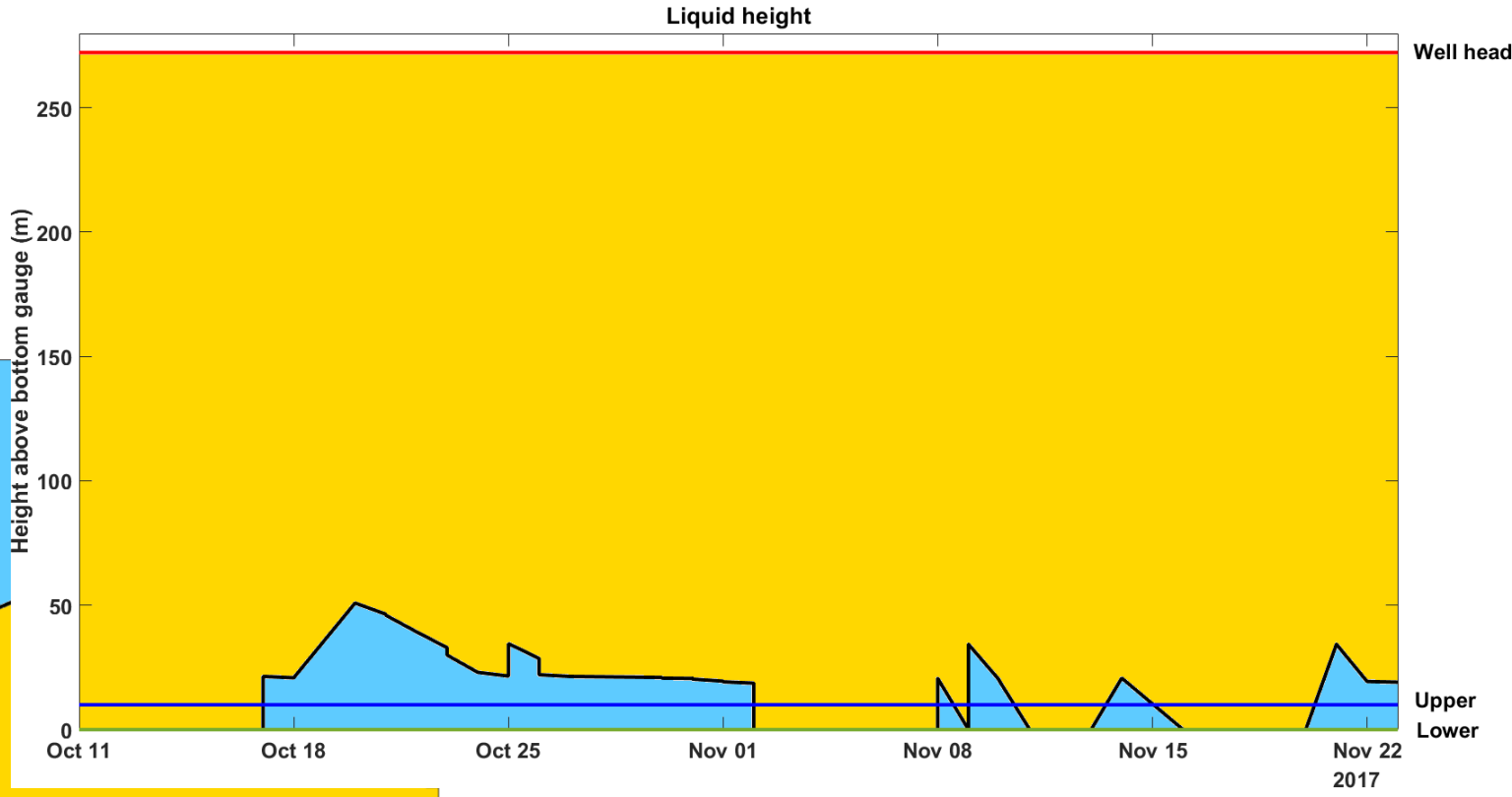

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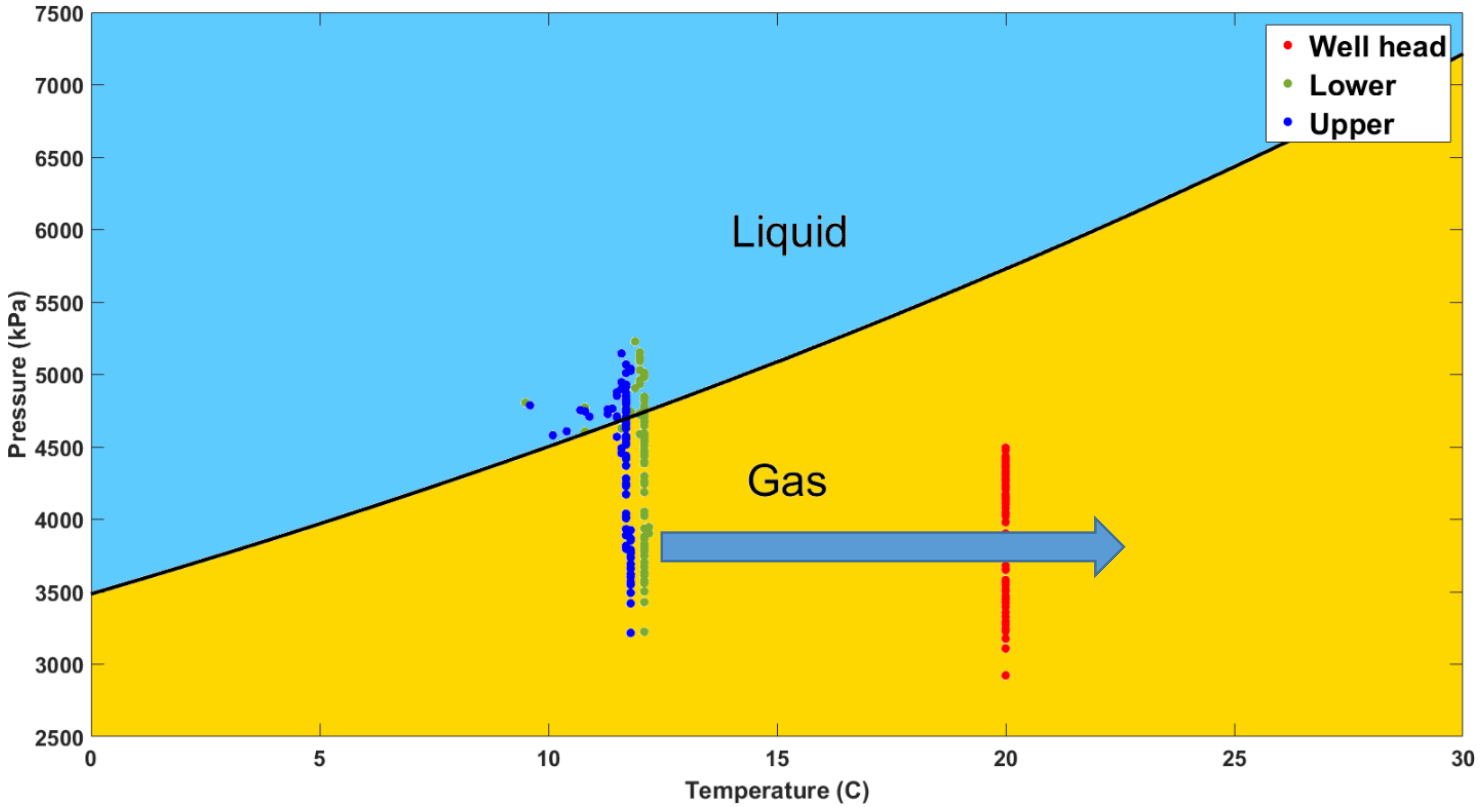
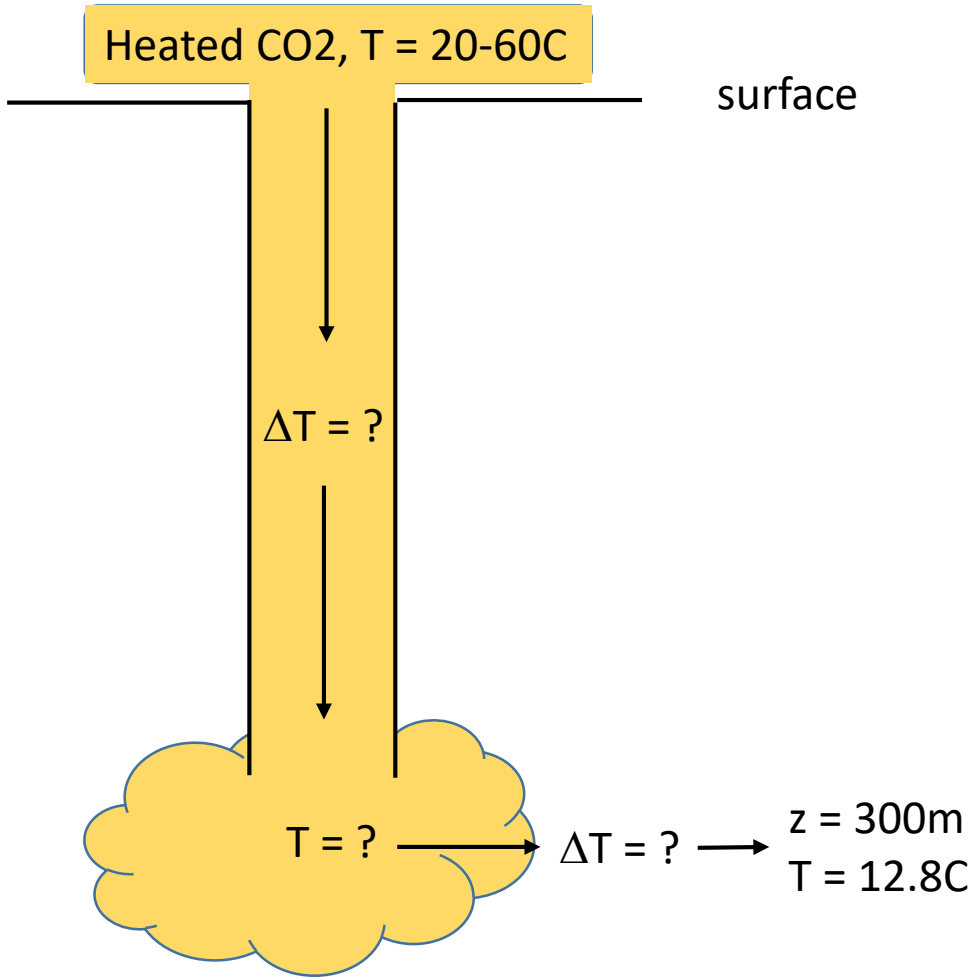
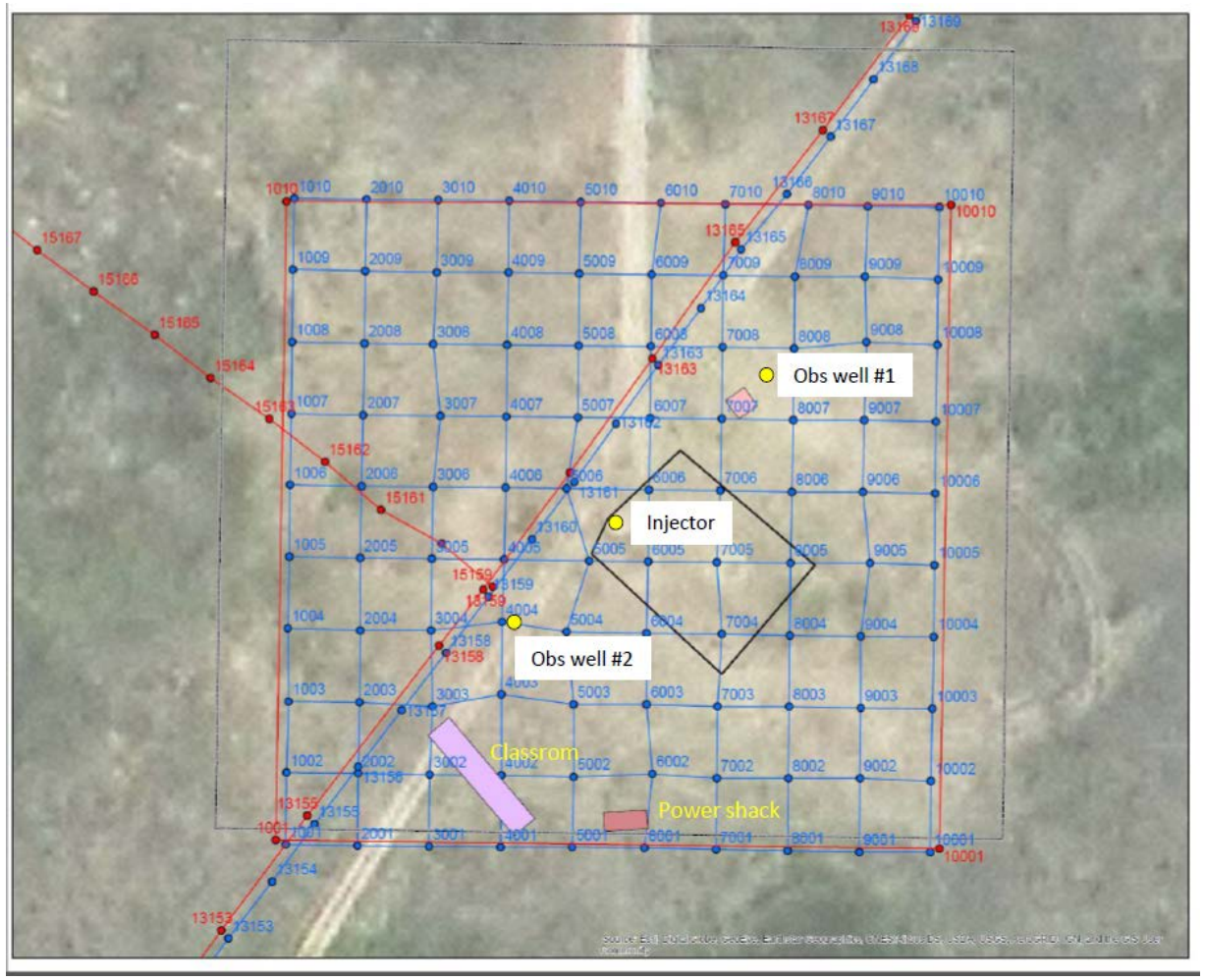


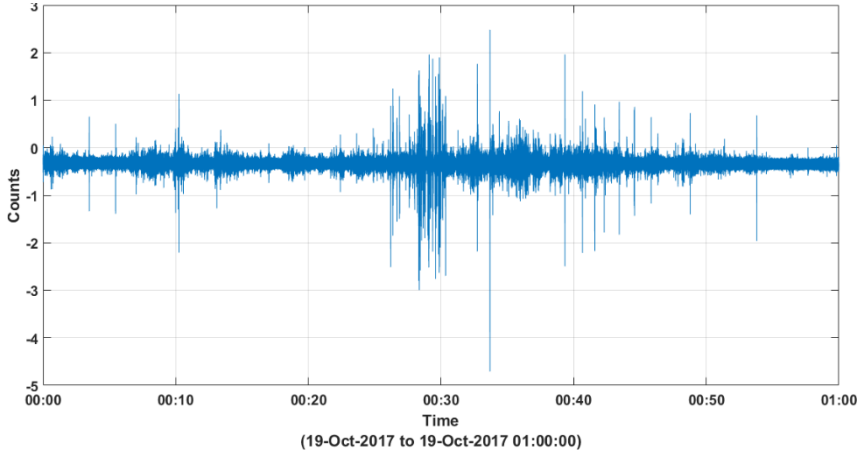


Continuous seismic data

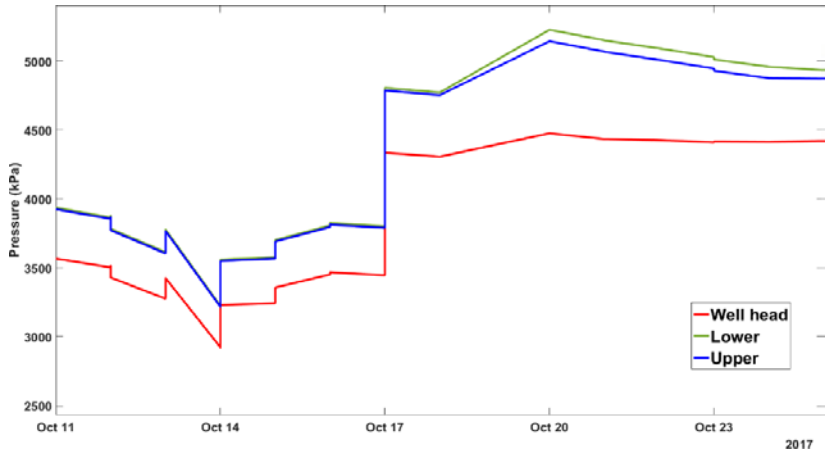


100 X 100m, 10m receiver spacing, buried at 1m

1) Continuous seismic data for 98 geophones from October 11th to October 25th (~360 hours)



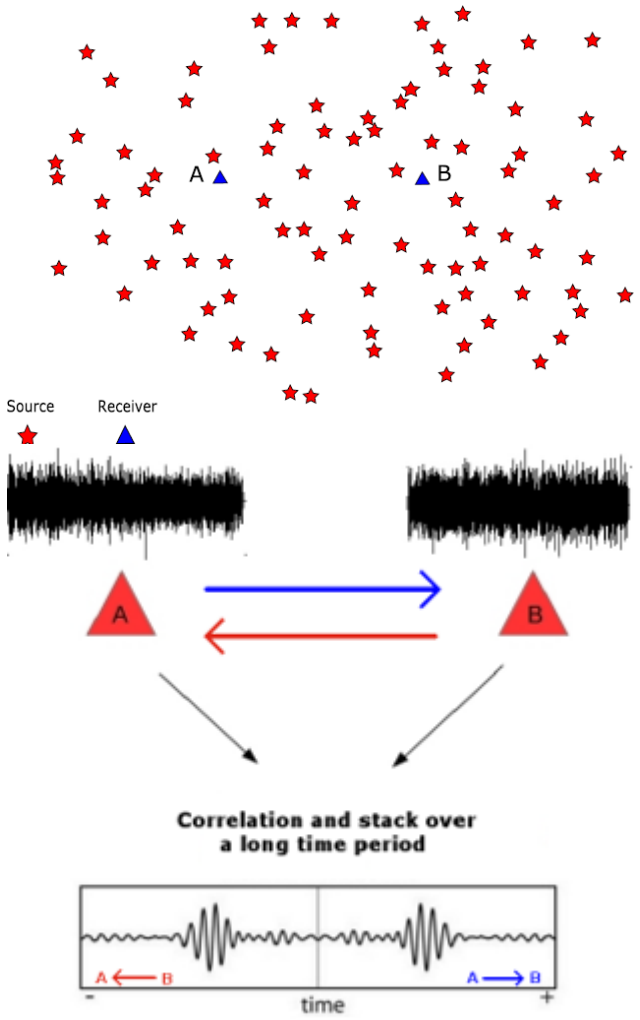
2) Injection test with pressure changes



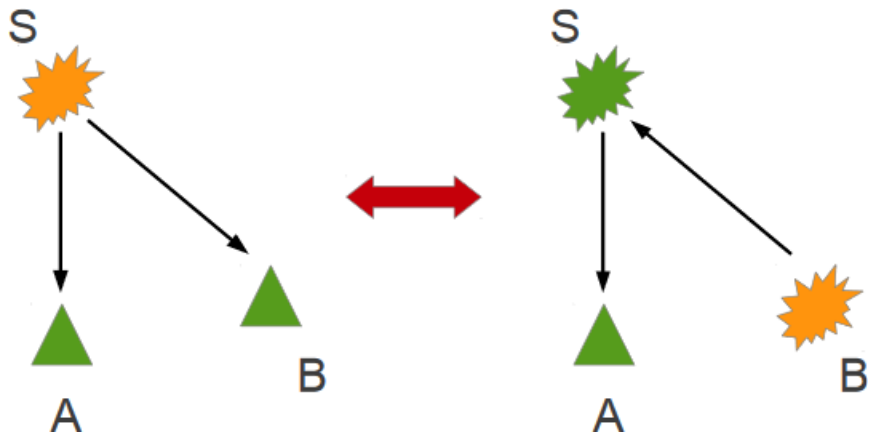
3) 3 days of active seismic (Vibe shots)

Ambient Noise Correlation – A little bit of theory

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



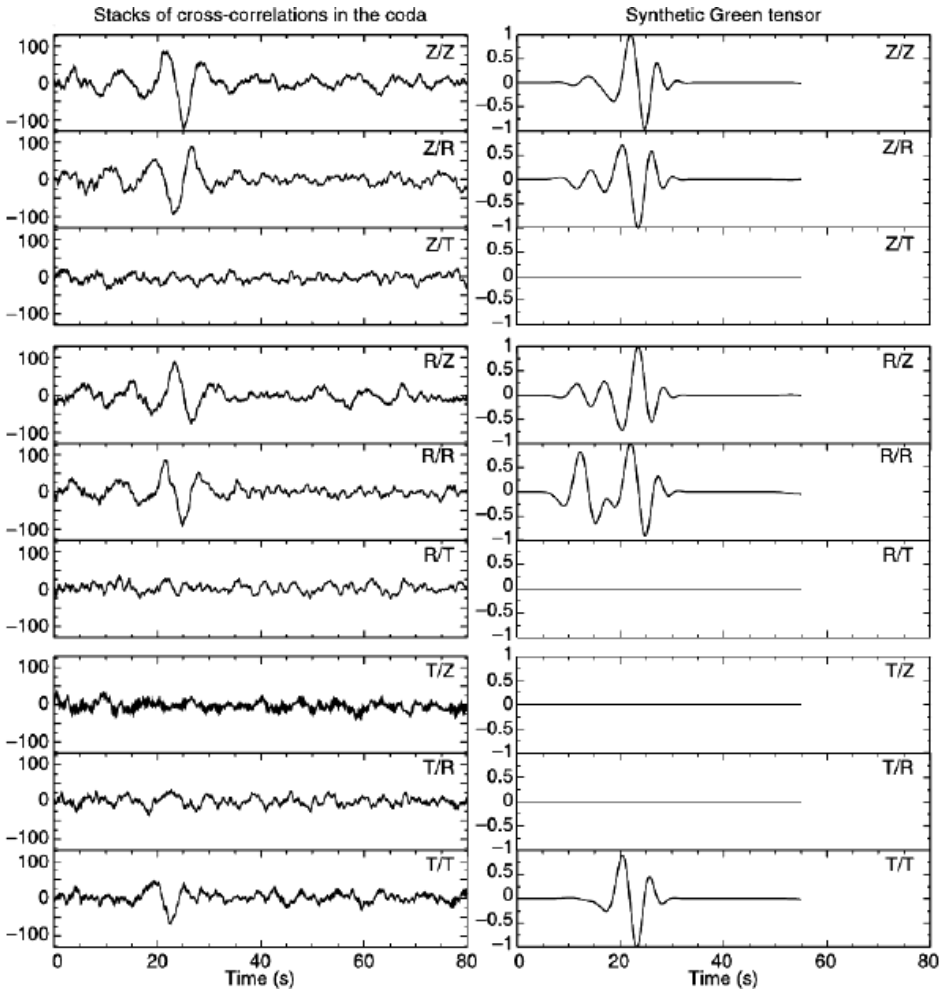
Analogy with the principle of time reversal (Derobe et al., 2003, Fink 1992)



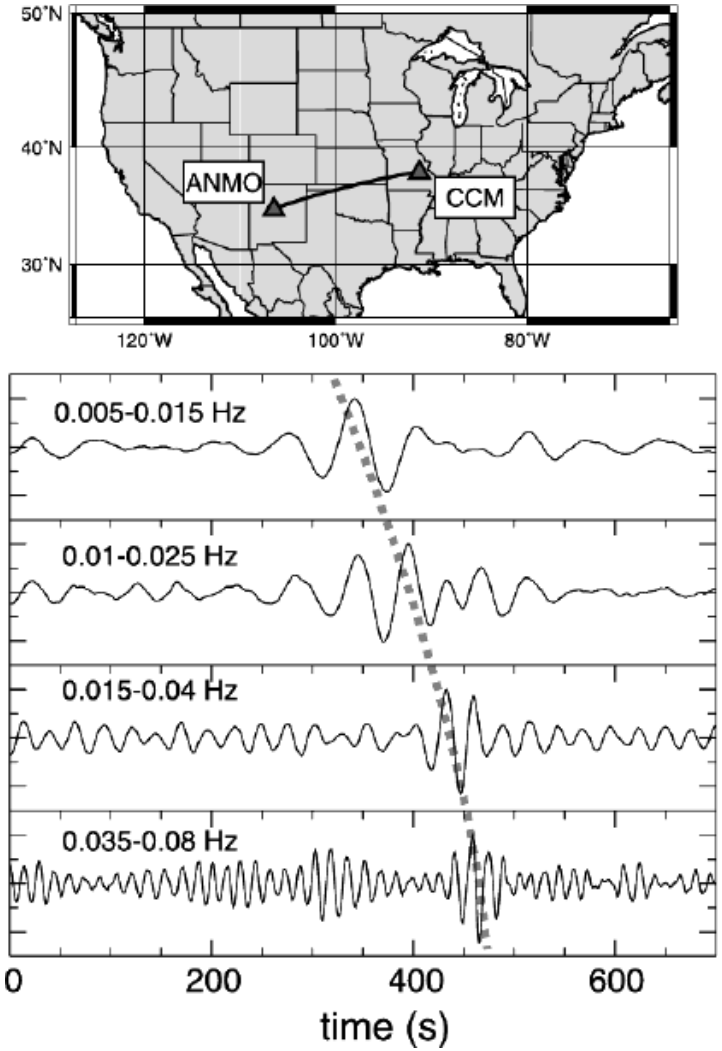
$$C_{AB}(\tau) = \int u_{SA}(t).u_{SB}(\tau - t)dt = G_{SA}(\tau) \otimes G_{BS}(-\tau) \otimes f(\tau)$$

Ambient Noise Correlation – A little bit of history

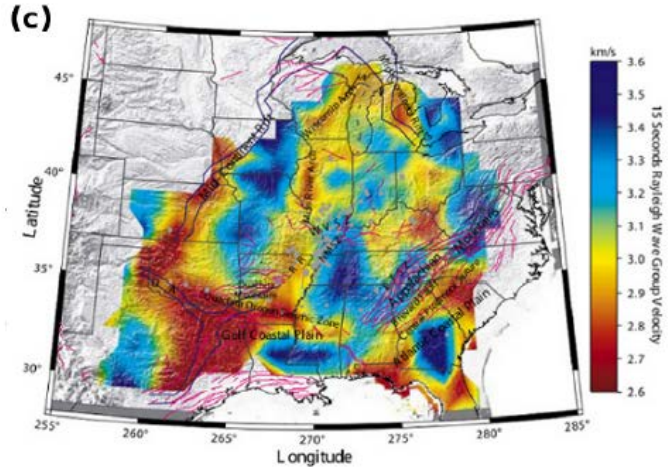
Using seismic coda,
Campillo and Paul, 2003

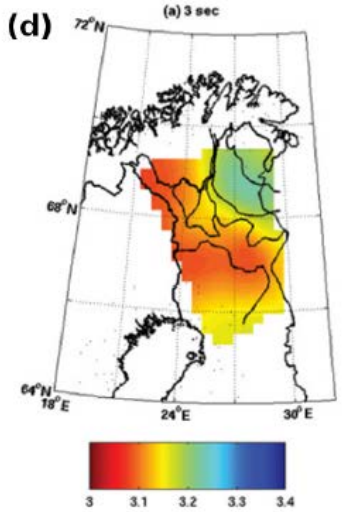


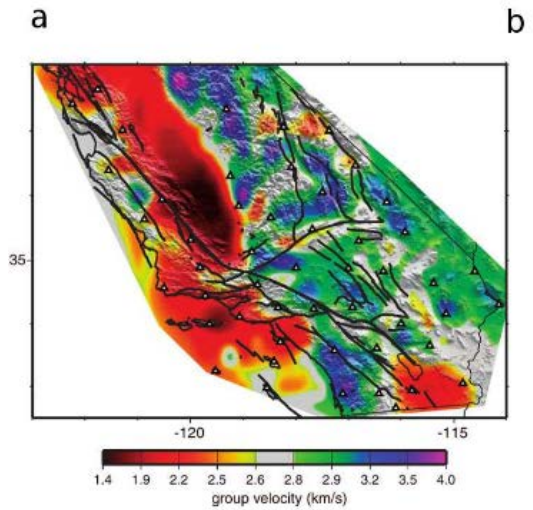
Using ambient noise,
Shapiro and Campillo, 2004

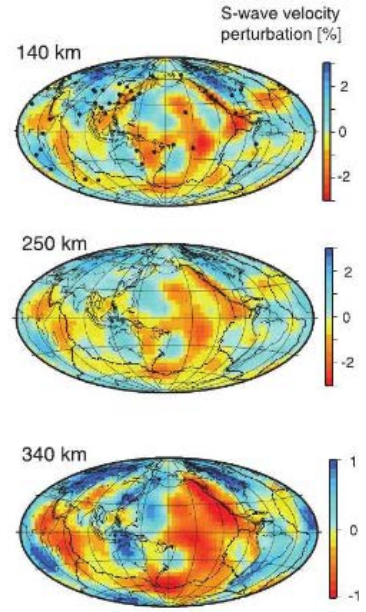


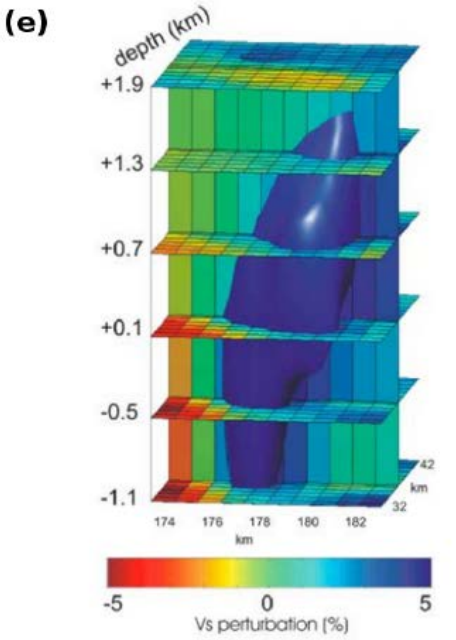
Ambient Noise Correlation – A little bit of history

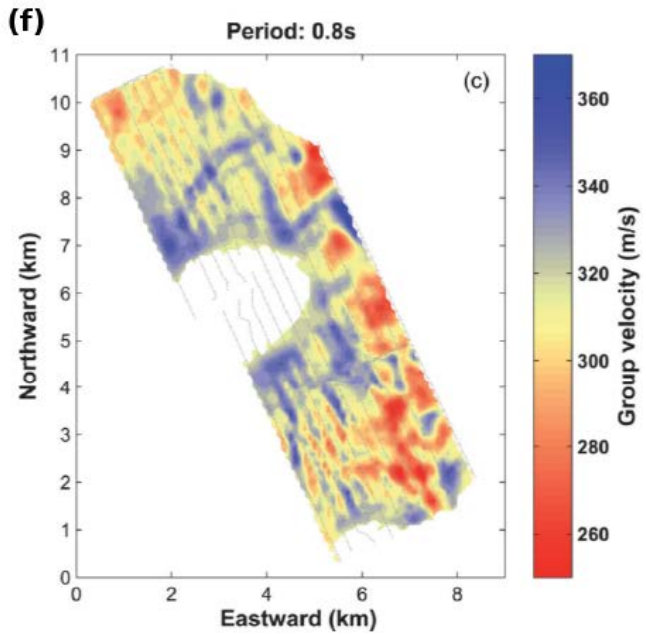


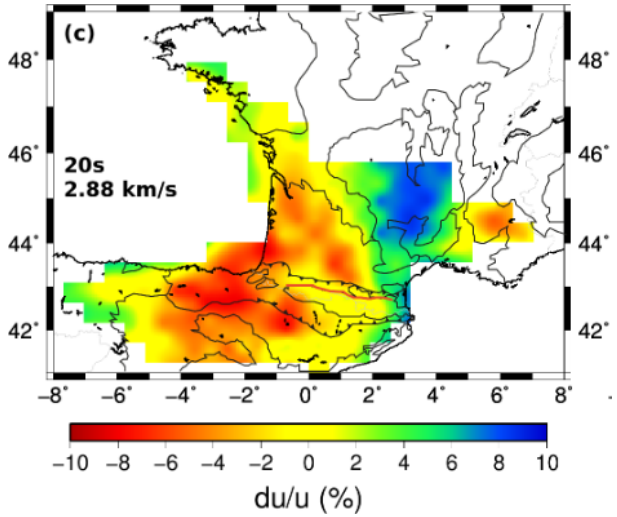






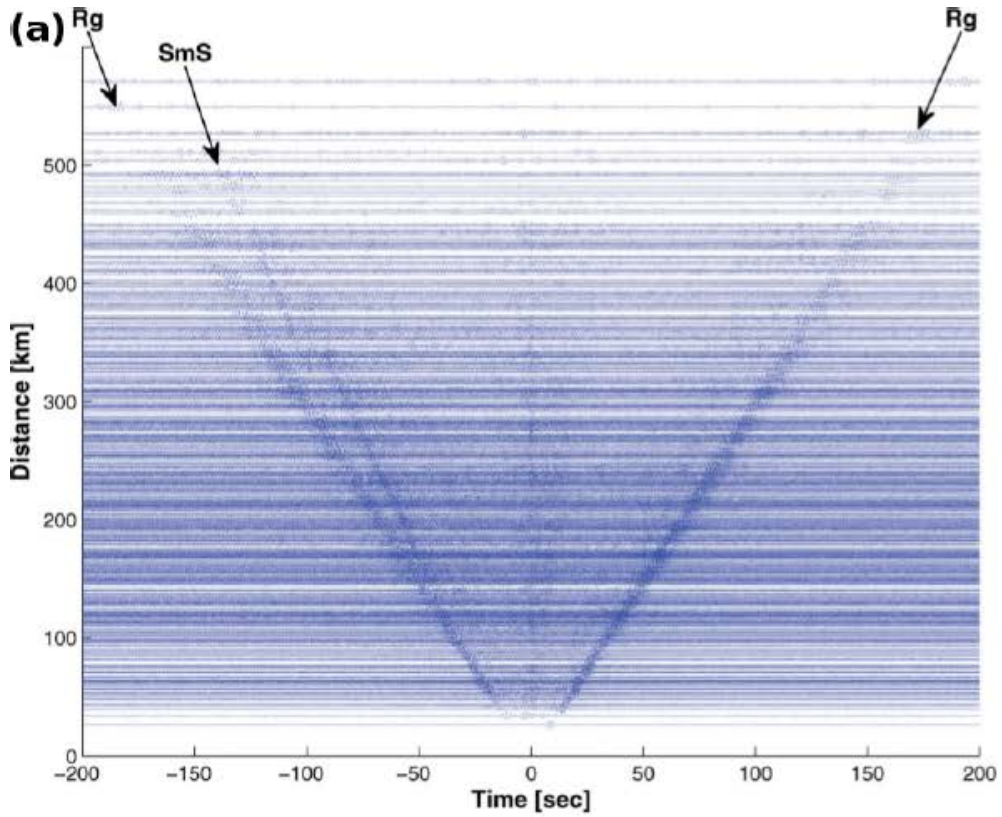






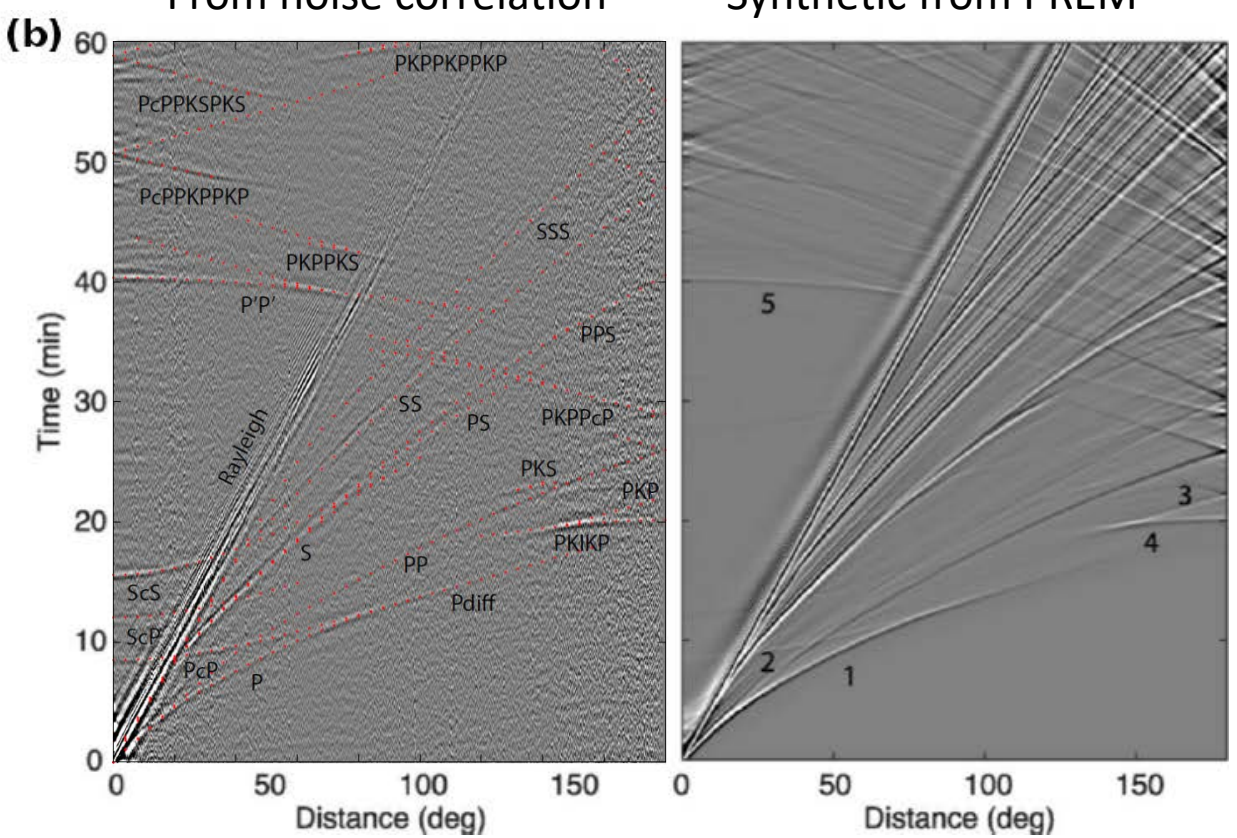
Shapiro et al, 2005
Brenguier et al 2007,
Liang and Langston, 2008
Nishida et al, 2009
Mordret et al 2013
Poli et al, 2013
Macquet et al, 2014
…

Ambient Noise Correlation – Volume waves observation



From noise correlation

Synthetic from PREM

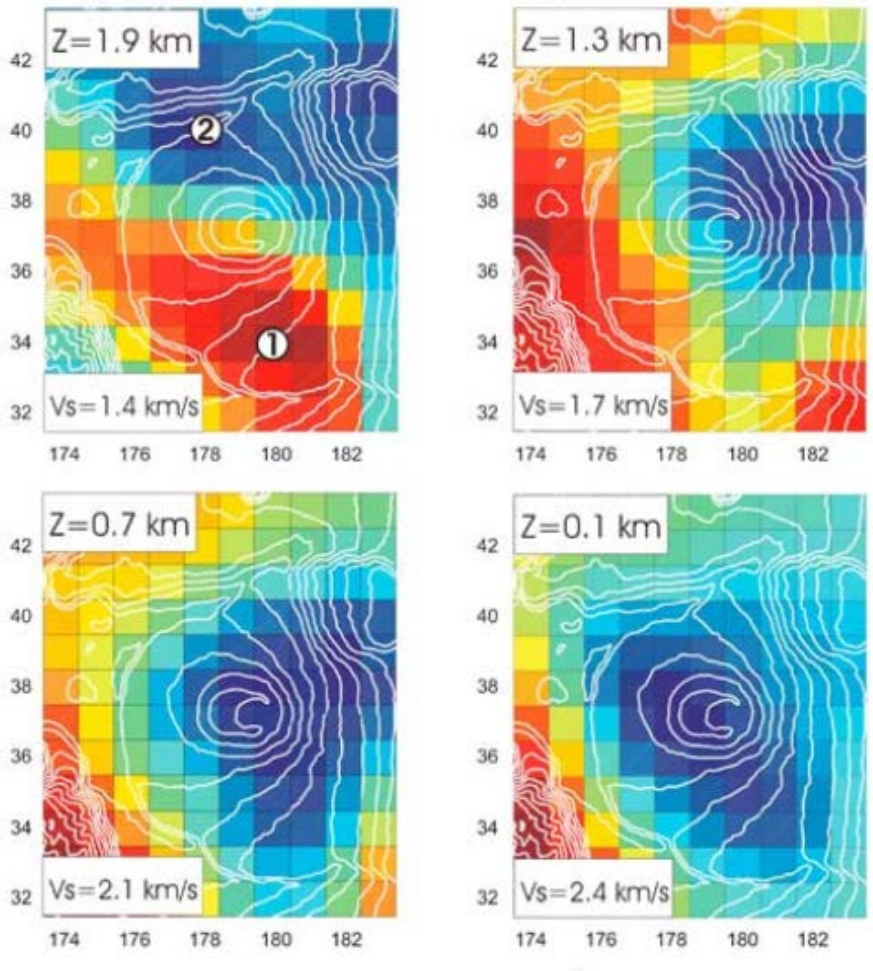


Poli et al., 2012,
S-wave Moho reflected

Boué et al., 2013,
Reflected and passing core volume waves

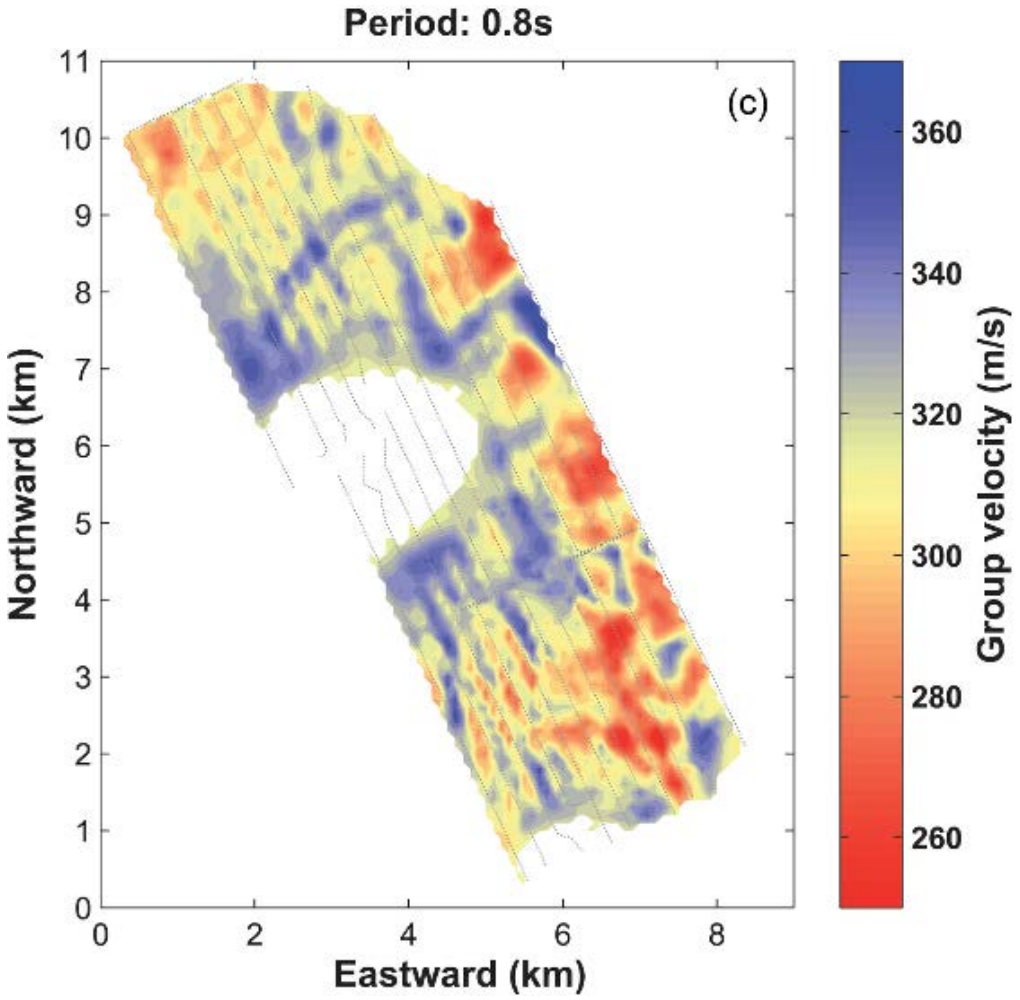
Ambient noise correlation – Exploration scale: Imaging

Volcano



Brenguier et al. 2006

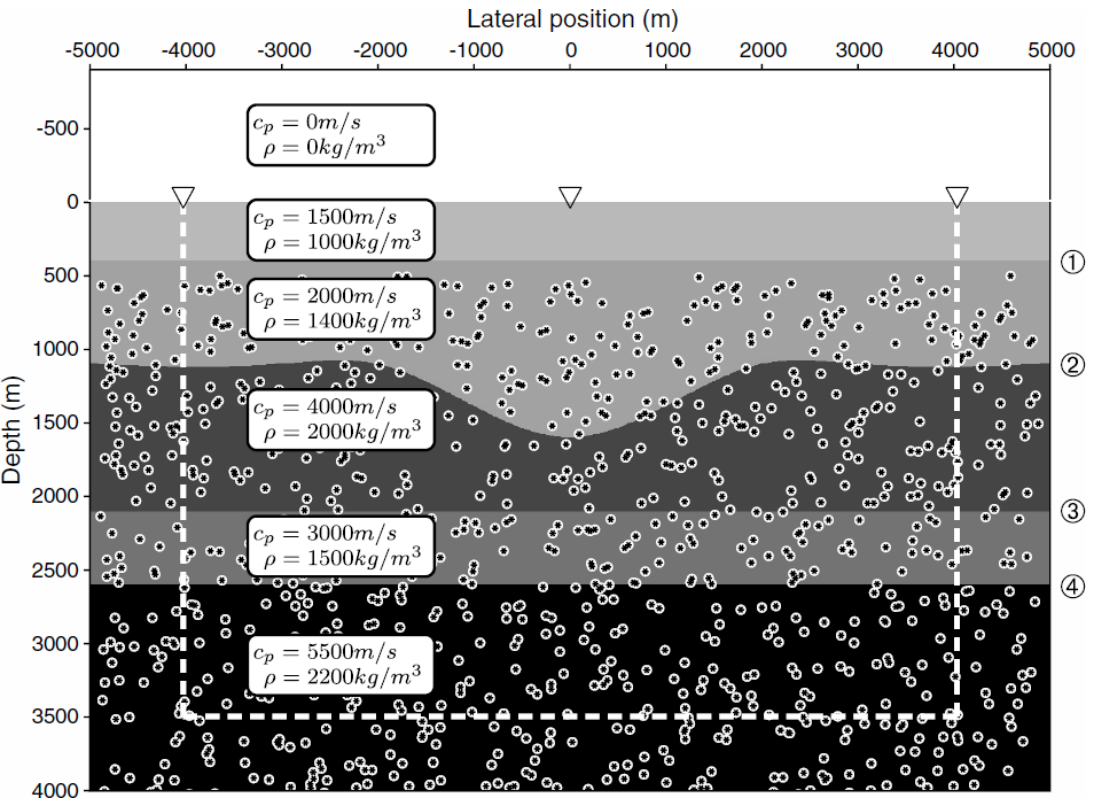
Valhall oil field

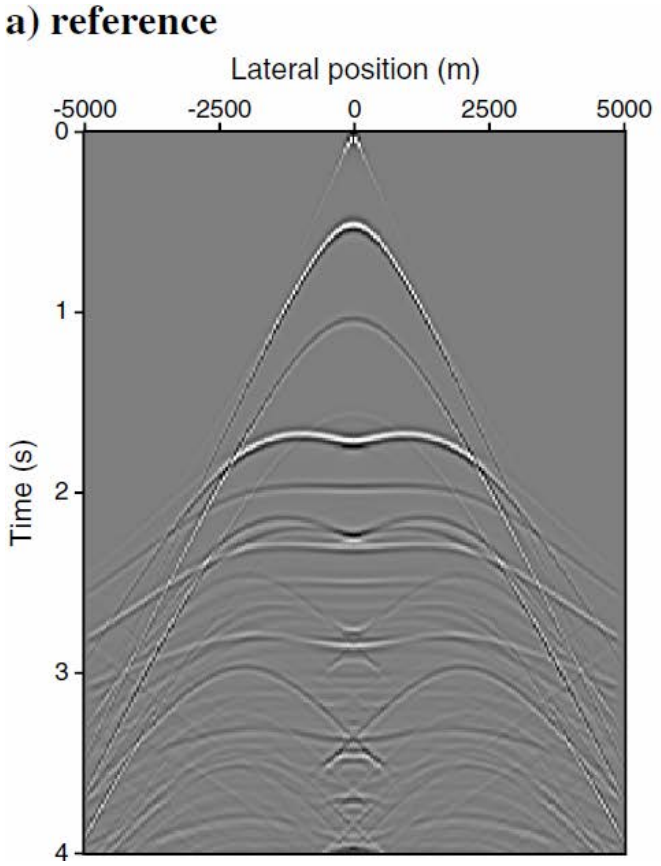


Mordret et al. 2013

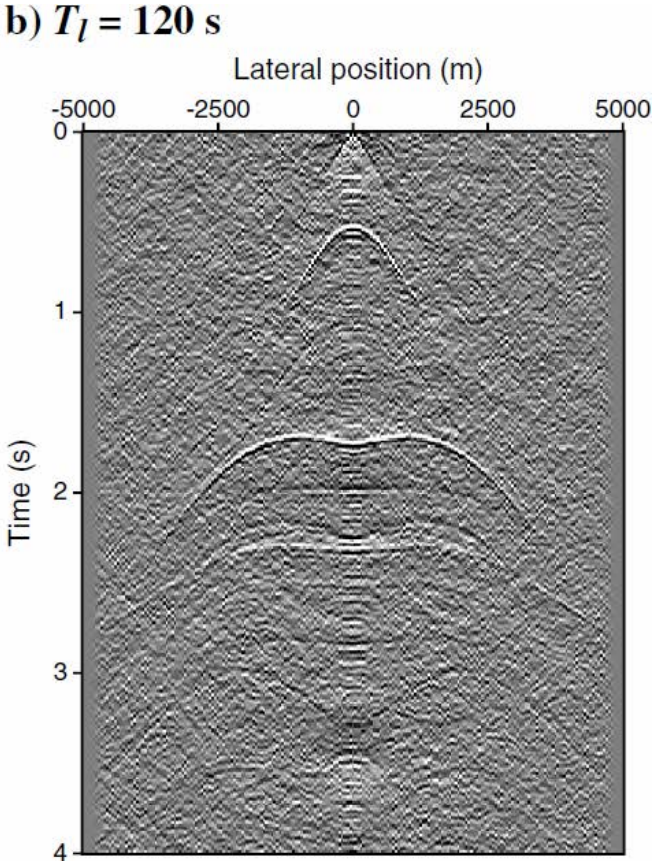
Ambient noise correlation – Exploration scale – Retrieving reflection data

Thorbecke and Draganov, *Finite-difference modeling experiments for seismic interferometry*, 2011



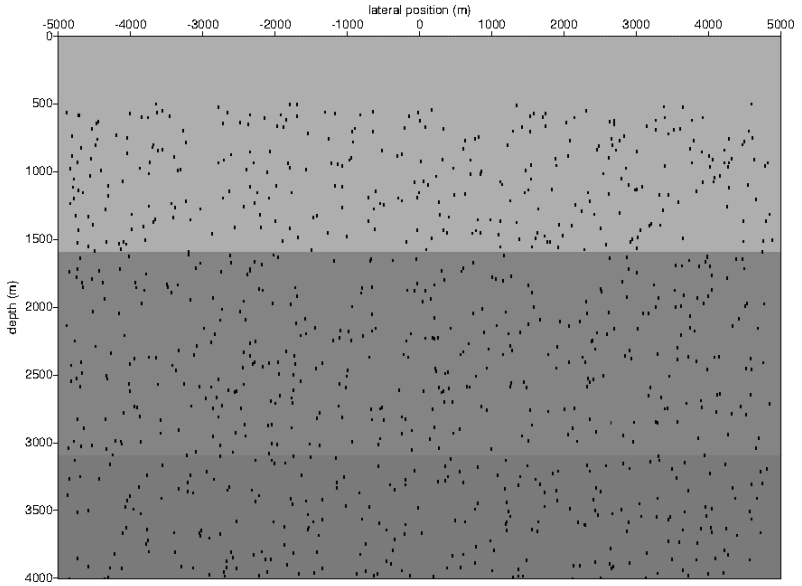


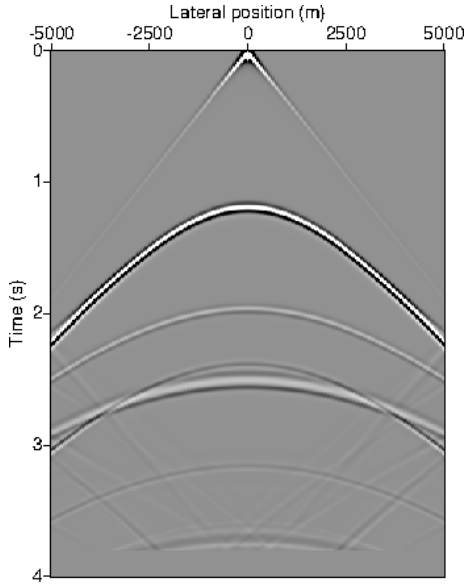
A directly modeled reference result for an actual source at x=0m

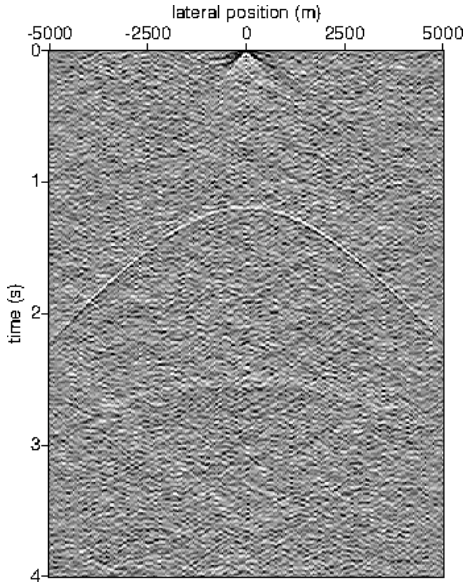


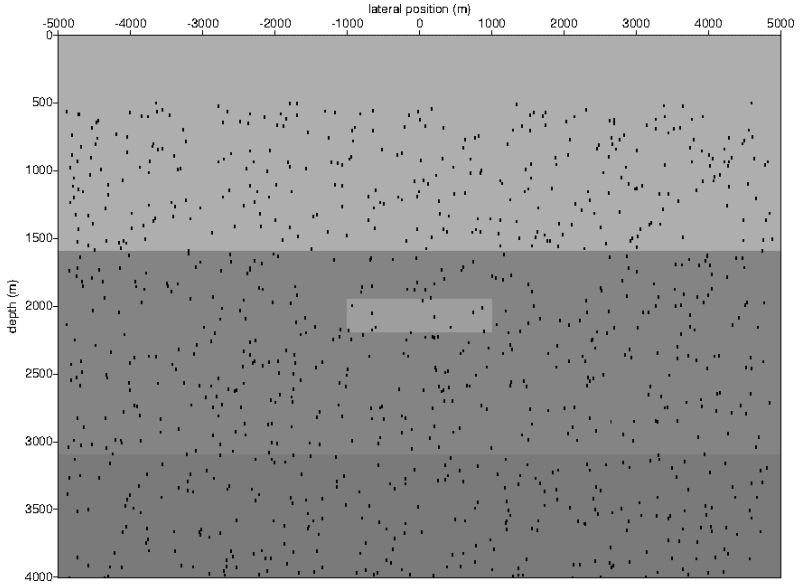
The retrieved reflection response for a virtual source placed x=0m, using noise correlation

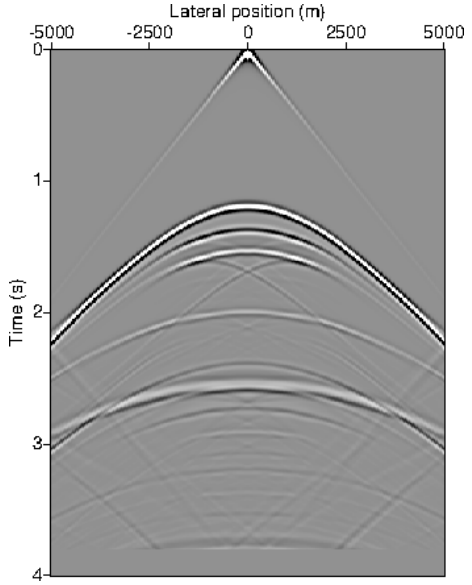
Ambient noise correlation – Exploration scale

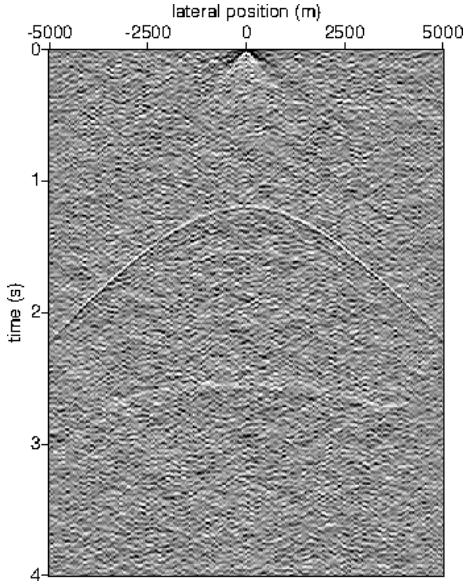








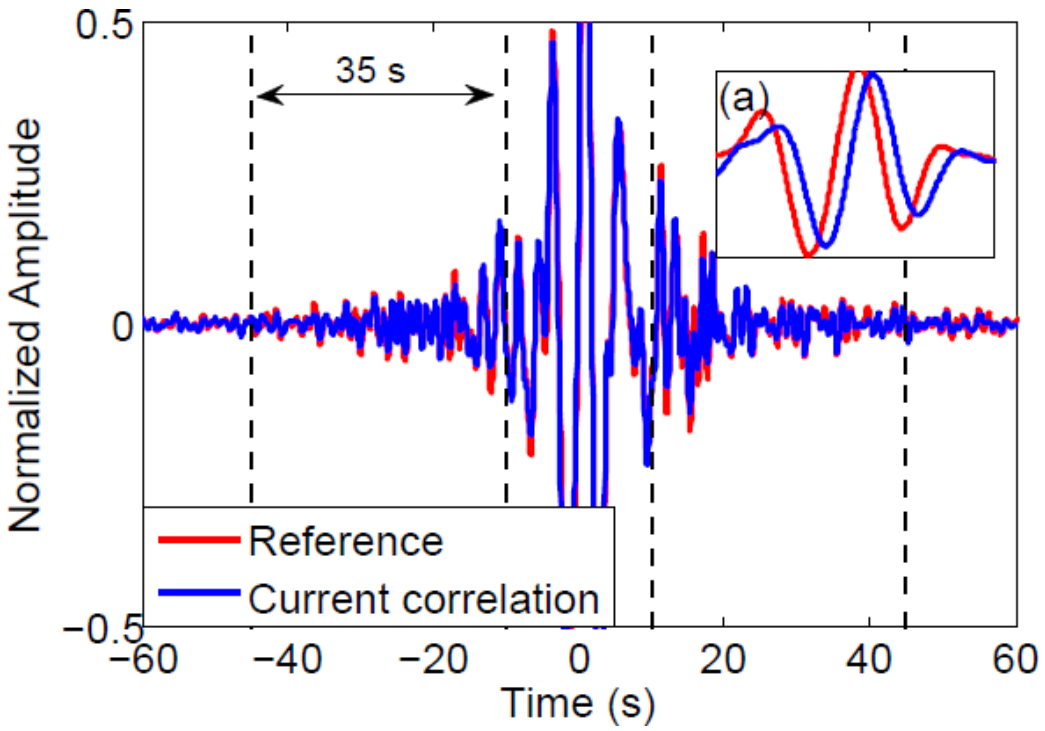




Vp variation : -10%
Noise duration : 60s

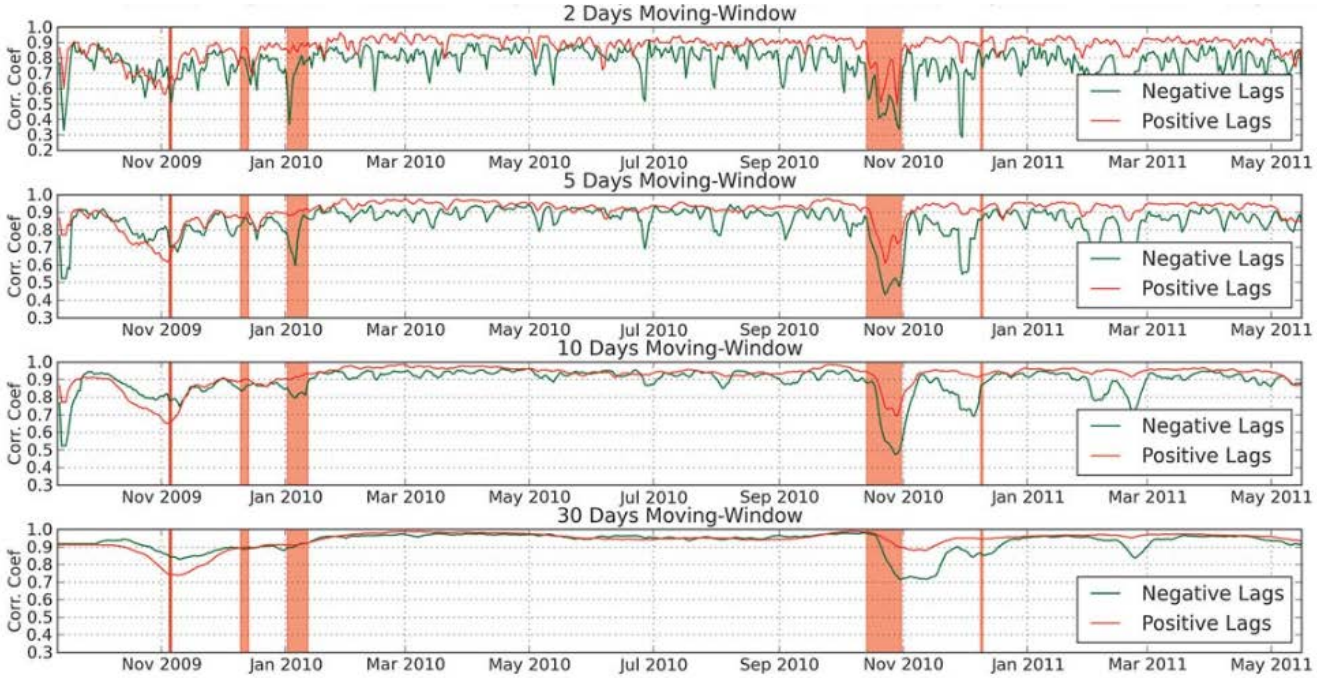
Ambient noise correlation – Monitoring

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



From Obermann et al., 2013

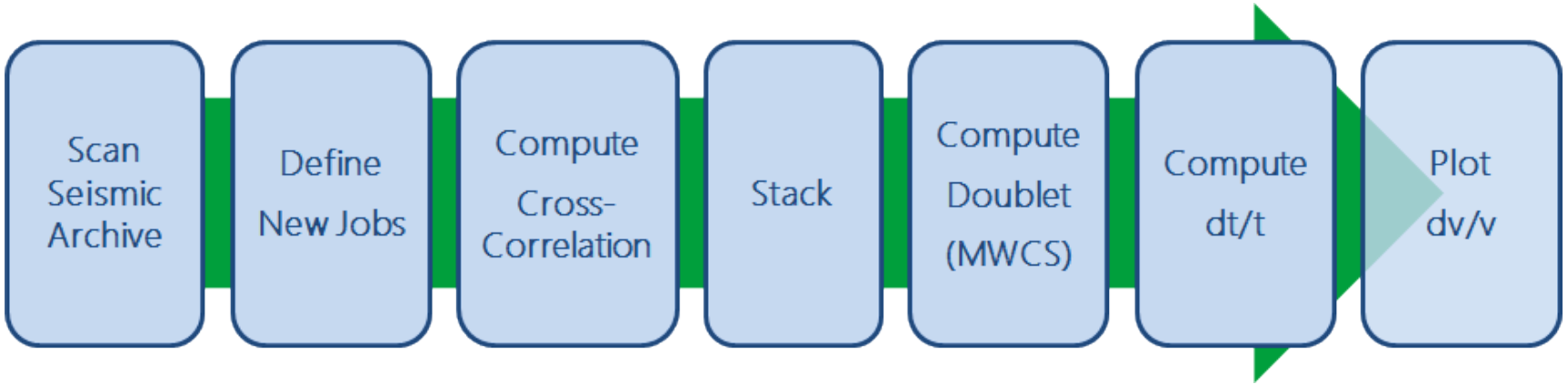
Computing the correlation function between a reference correlation and the current correlation



Lecocq et al., 2014

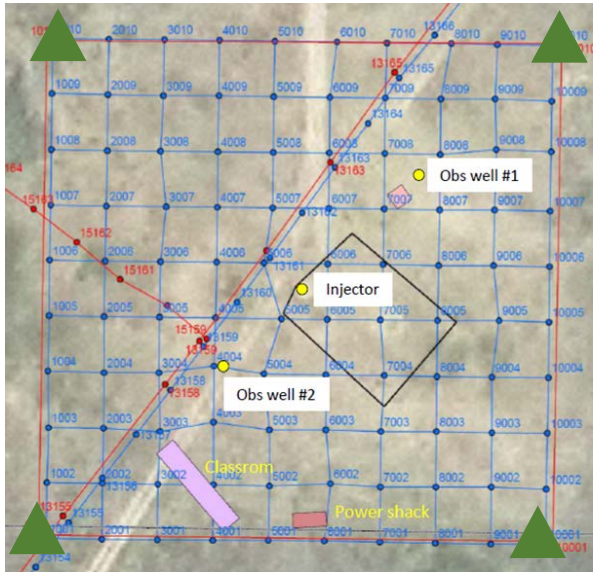
Ambient noise correlation – Monitoring

MSNoise, a Python Package for Monitoring Seismic Velocity Changes Using Ambient Seismic Noise,
T. Lecocq, C. Caudron and F. Brenguier, Seismological Research Letters, 2014

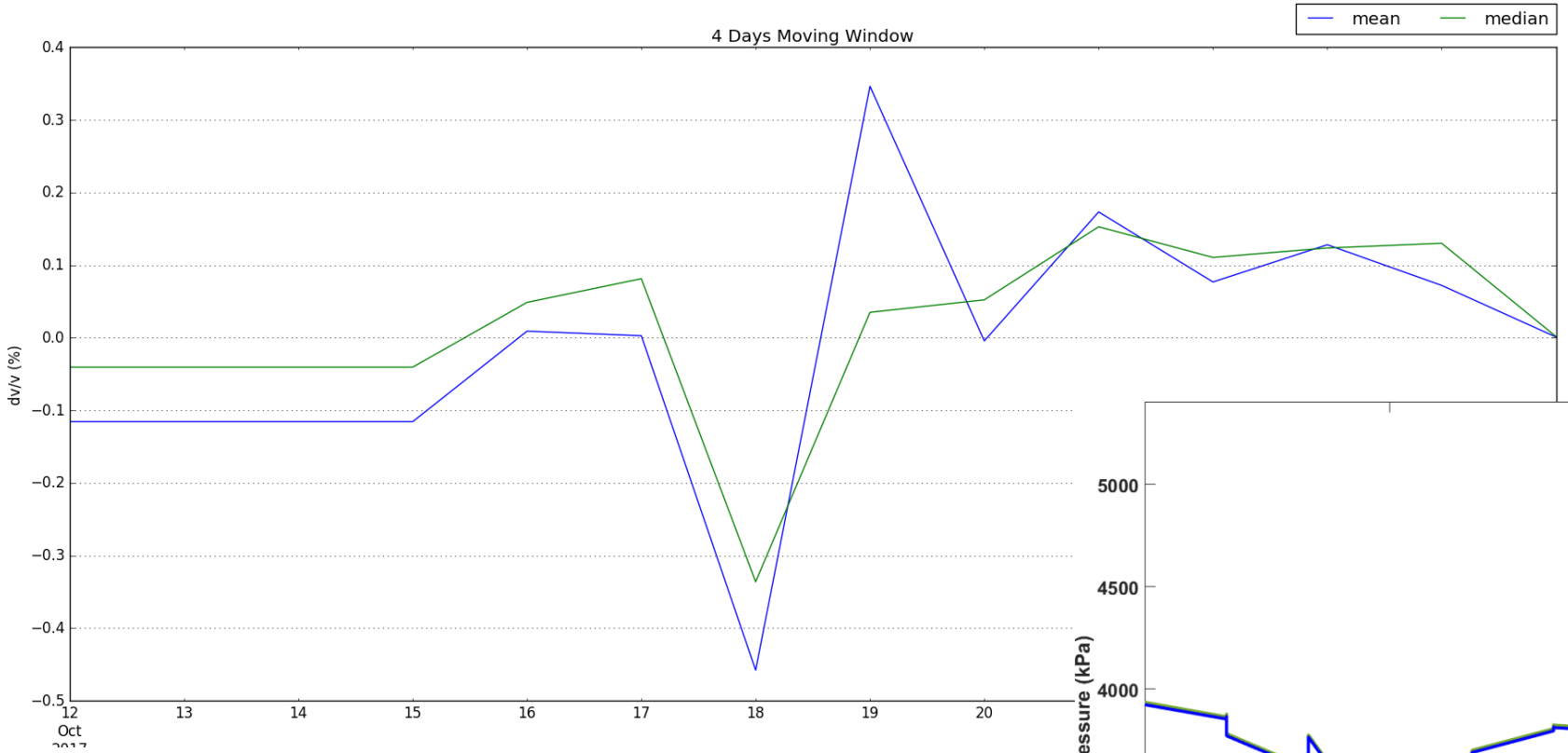


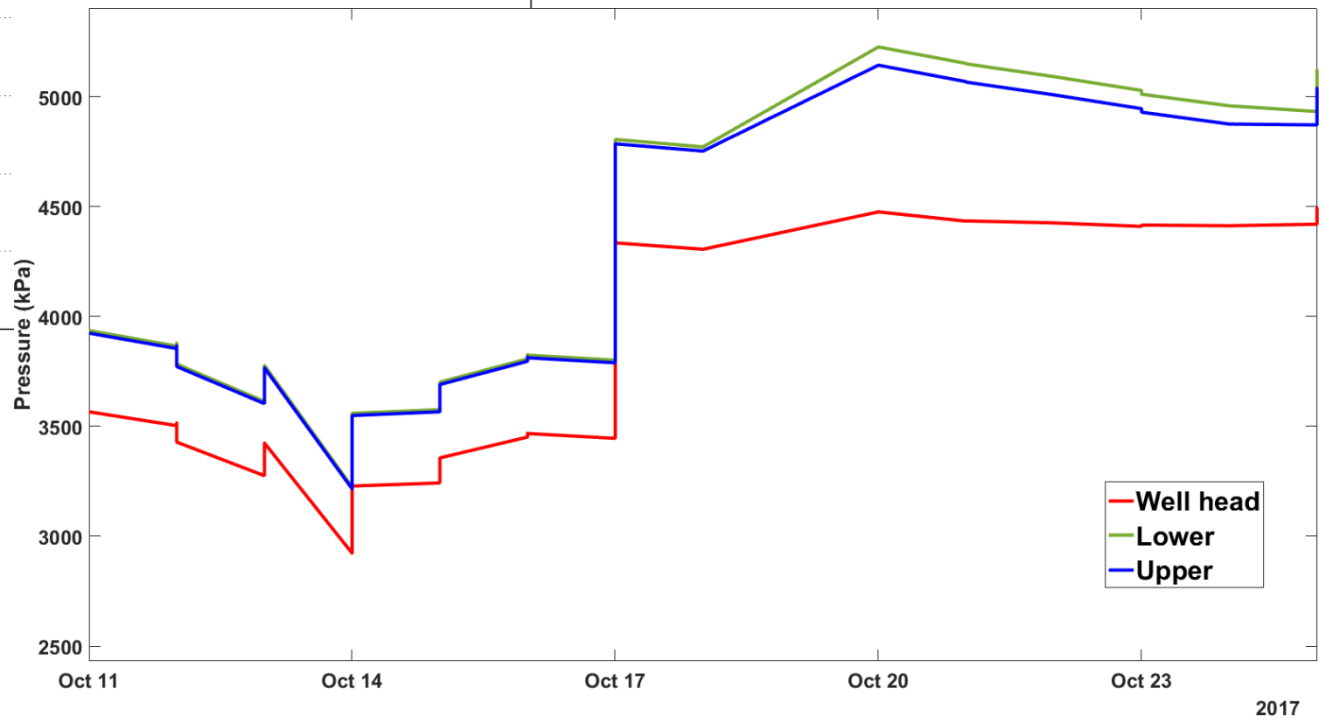
- Usual processing implemented (filtering, 1-bit, spectral whitening…)

- Moving-Window Cross-Spectral method to study the relative dephasing between Moving-Window stacks (“Current”) and a Reference (Clarke et al., 2011)



Ambient noise correlation – Monitoring





Ambient noise correlation – Regionalization of temporal changes

St. Gallen geothermal site, change of pressure from 7.5 to 44.5MPa

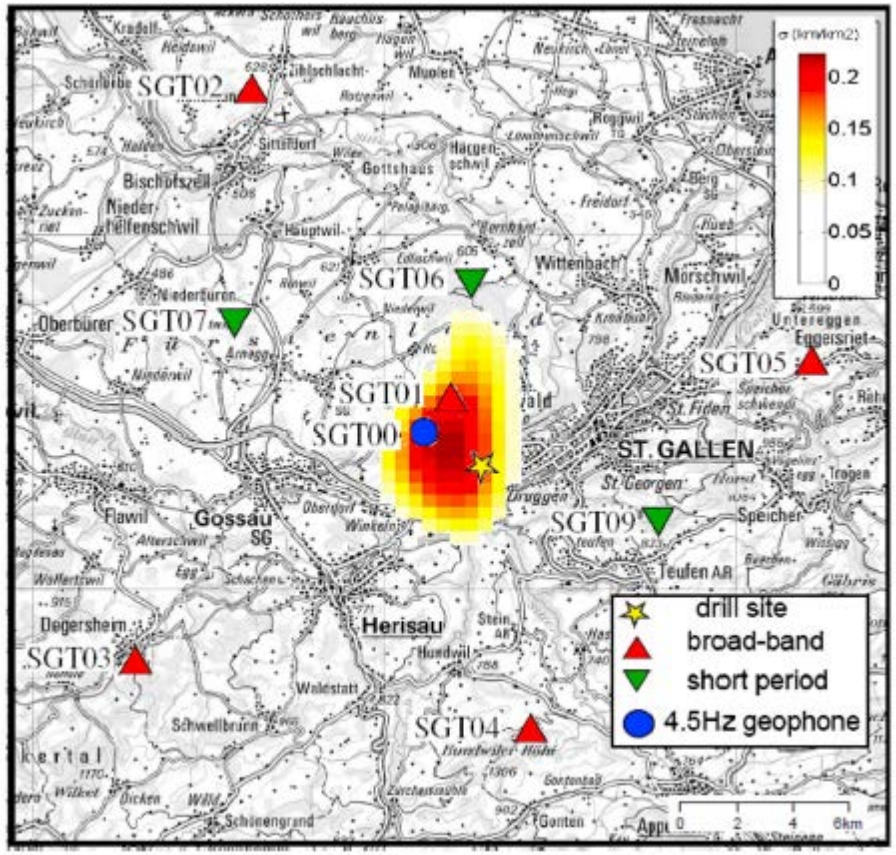
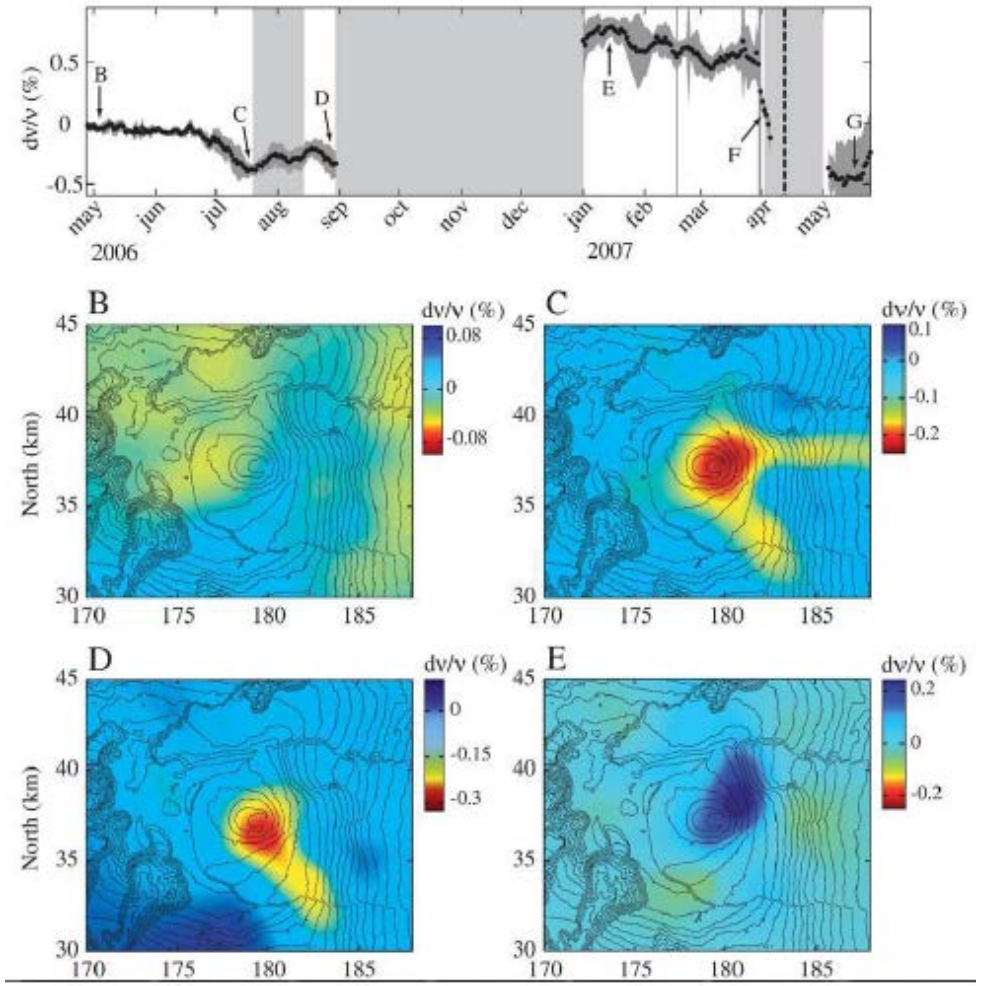


Figure 9. Scattering cross-section density changes derived by least squares inversion averaged over July 2013. The observed changes are around the injection well, indicating a causal relationship with the activities at the well.

Obermann et al., 2015

Volcanic eruption, Piton de la Fournaise



Duputel et al., 2009

Conclusions

On-going work and future plans :
- Updating the geostatic model by time history matching
- Loss temperature modelling & non-isothermal fluid flow simulation

Concerning the ambient noise :
- Retrieving reflection data using simulation => application to real data
- Monitoring using inter-station correlation => if working, regionalization of temporal changes

Ambient noise correlation method advantages :
- Passive method
- Allowing to estimate the medium change

Ambient noise correlation method disadvantages :
- How to deal with a huge amount of data (15 days of continuous data, 98 stations => 1.3To)

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