Microseismic monitoring of fluid injection at the Longyearbyen CO₂-Lab, Svalbard

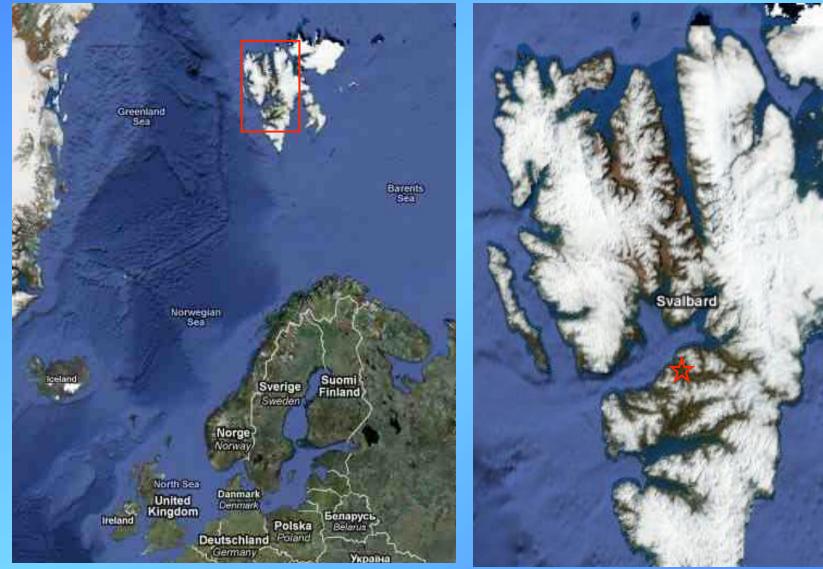
Volker Oye¹⁾, Peng Zhao¹⁾, Hom Nath Gharti¹⁾, Daniela Kühn¹⁾, Alvar Braathen²⁾ ¹⁾ NORSAR, Gunnar Randers vei 15, 2007 Kjeller, Norway, ²⁾ The University Centre in Svalbard, UNIS, Norway, volker@norsar.no







CO2LAB project







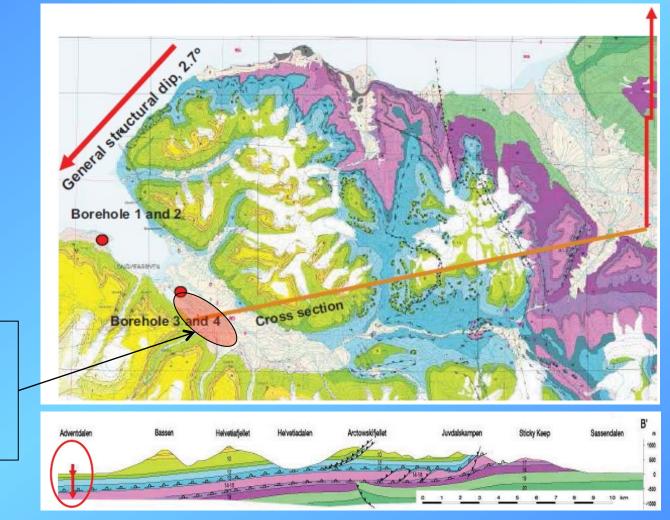
Project goals

- The CO2LAB project has investigated that a sealing cap rock section exists around Longyearbyen, and it will proceed towards demonstration and monitoring studies of sub surface CO_2 storage over time. NORSAR's involvement in this project contains 3 main topics about:
- 1. Establish and improve the microseismic network in order to locate and improve microseismic event locations
- 2. compute changes of stress fields resulting from variations in the geometry and rock properties of the CO_2 storage
- 3. model changes in 4-D seismic response due to CO_2 injection/ propagation, i.e. model pre-stack depth migrated sections





Geological map of the Longyearbyen region

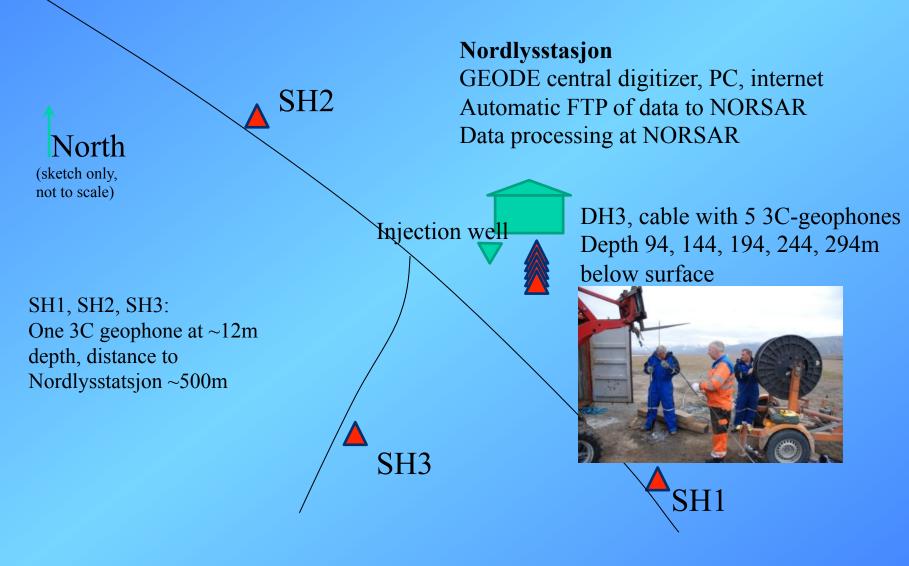


Area of installed microseismic network





Station network at Longyearbyen, Svalbard







Nordlysstasjonen





Installation 5-level 3C geophone string in deep borehole (94 to 294 m depth, 50m distance)









Installation 5-level 3C geophone string in deep borehole (94 to 294 m depth, 50m distance)









Installation of single 3C geophones in shallow borehole stations (12m deep)

Installation at SH3







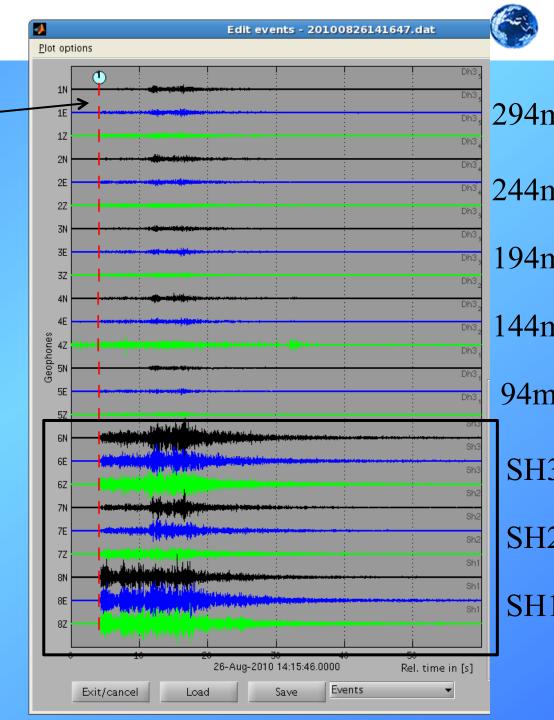


Installation at SH1

NORSAR

P-wave of earthquake from Storfjorden

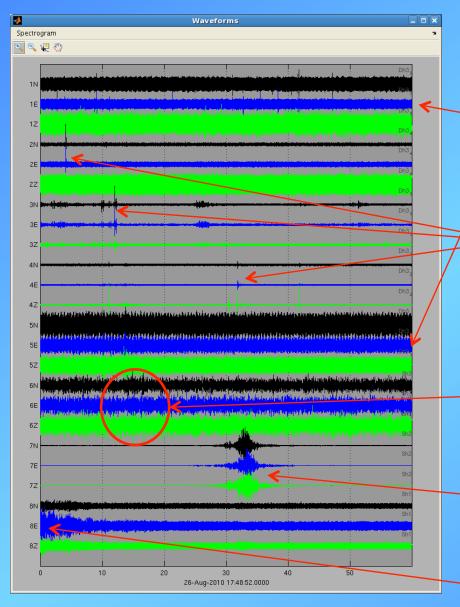
In principle, the polarization of the earthquakes can be used to orient downhole sensors. However, it is difficult due to energy at low frequencies. We used also local events to get more consistency within geophone levels.







Some typical recordings



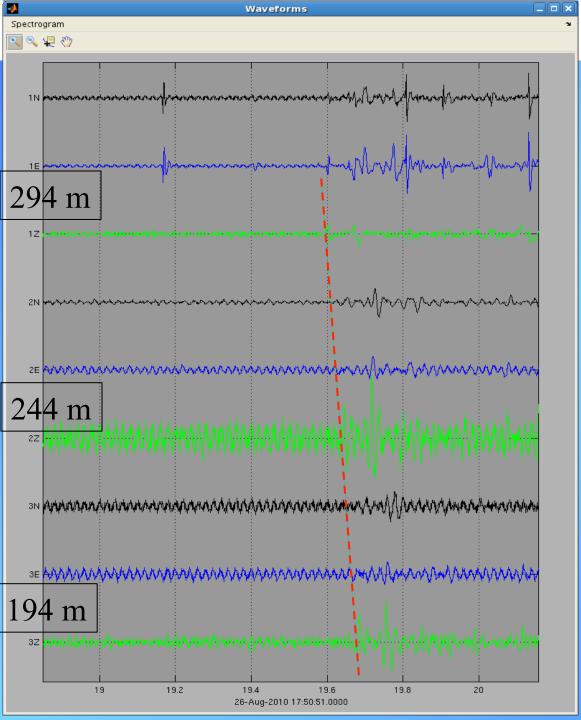
L5 and L1 are very quite, only constant background noise L2 L3 and L4 show some spikes with local noise that peaks far above the constant background noise

Car driving by station SH3, too far a

Car driving by station SH2

Car drove by station SH1



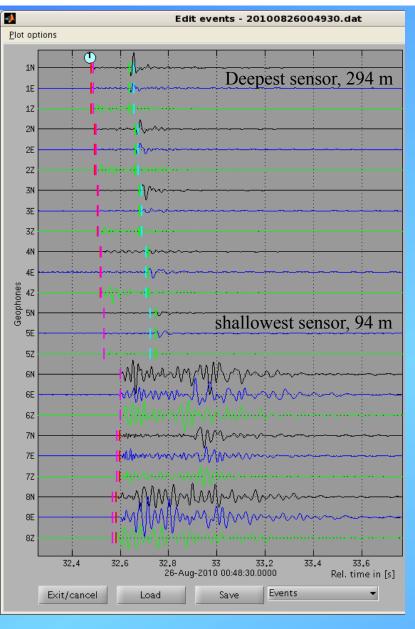


Many automatic detections (about 1000/ day) with apparent velocity of ~1000 m/s, only visible on the deepest 3 sensors, coming from depth.

Mud waves along the open hole section?

NRSAR

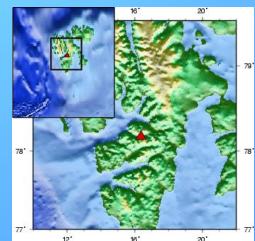


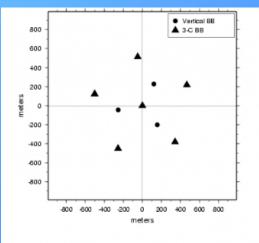


Event on 26th August at 00:49 GMT

(26th 2:49 local time)

- strongest local event located so far, clearly seen on all stations, signal is far above noise-level.
- P and S phases can be clearly identified at downhole string, on shallow borehole stations Pwave arrivals are clear, but S-wave arrivals remain more difficult.
- location trade-off between depth and spatial position (direction North-East).
- signals are also found on all stations of NORSAR's array SPITS, about 12 km east of the injection site – will help to confine the location!

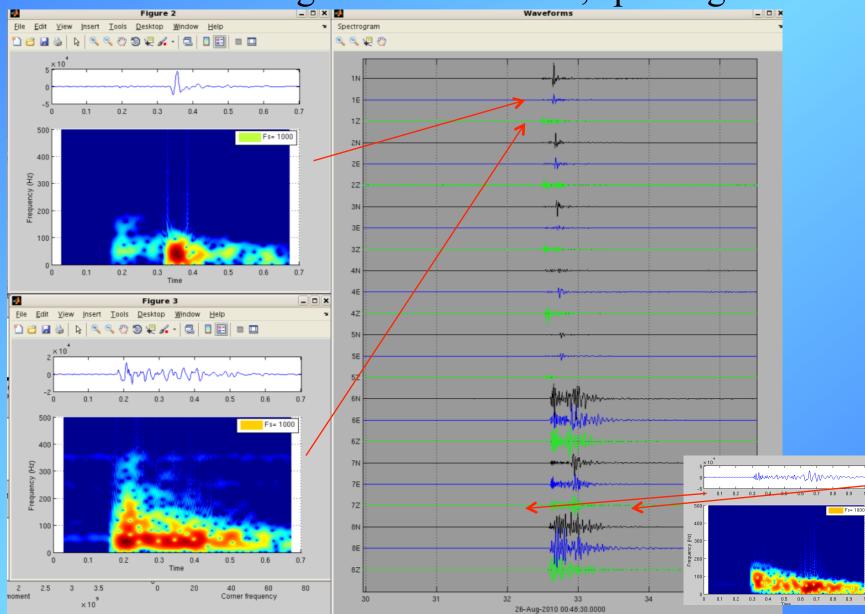




NRSAR



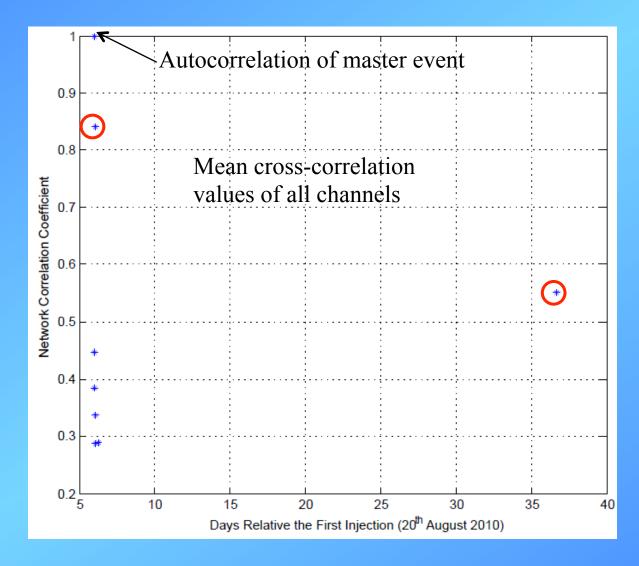
Event on 26th August at 00:49 GMT; spectrograms





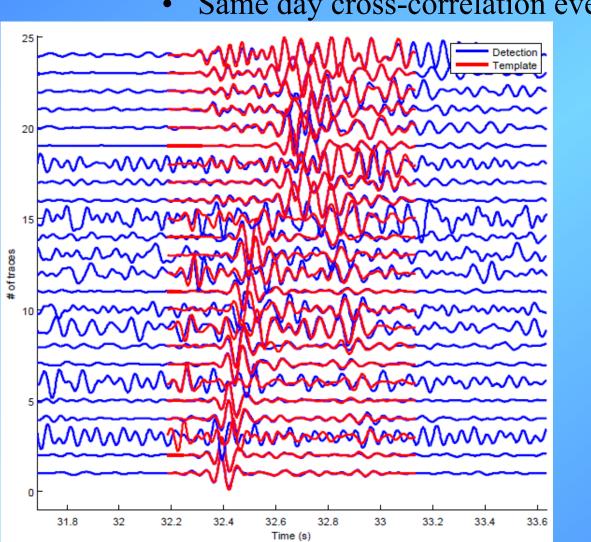


Network cross-correlation coefficients







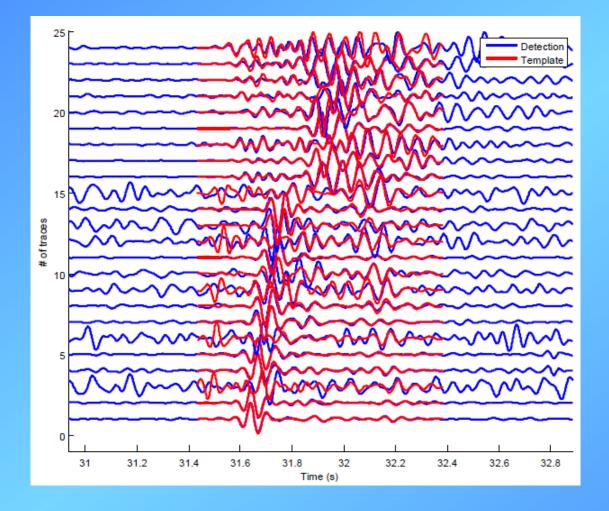


Same day cross-correlation event •





Detection 30 days later than main shock



What is the nature of the microseismic events that started ~17 hours after shut-in of a 5-day water injection experiment?

earbyen 1) Induced due to water injection experiment?2) natural local seismicity?

(sketch only

not to scale

Injection well

ASH3

DH3

SH1

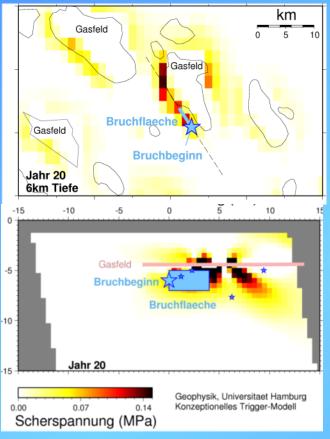
Approx.epicentre

Steps towards a good answer:
include SPITS stations in location
refine P and S wave velocity model
find repeater events and provide
better depth estimate for location
do stress field modeling





Calculation of stress field changes due to filling/draining of reservoirs



Gas reservoir Reactiveted weakness zones

Schematic view after Segall et al., 1998

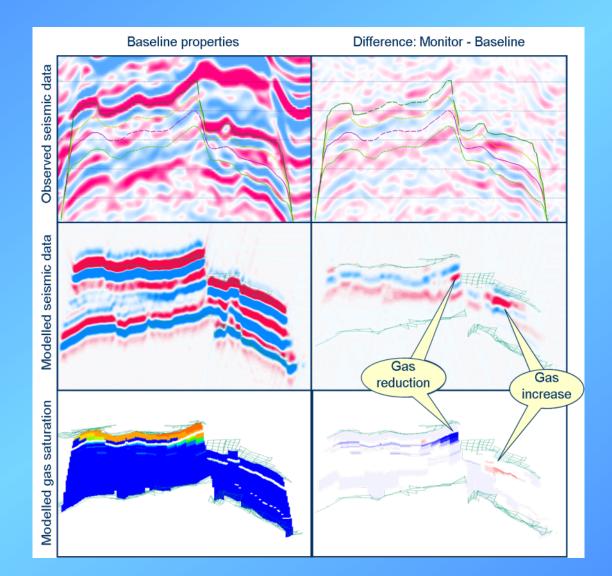
Shear stresses at 6 km Depth and along fault plane

(Conceptual model from Dahm et al., 2010)





4D seismic modeling to simulate behavior of migrated seismic sections on a time-lapse basis during long term CO2 injection







Conclusions

- The installed microseismic network is up and running, providing real-time data-flow.
- Continuous mode will soon be exchanged with triggered mode recording (low trigger threshold).
- Microseismic events occur at depth, direct correlation between events and injection test is likely, but needs to be further investigated.
- Not all data have been analyzed automatically, and visual/manual re-processing is inevitable. Need to work with automatic discarding of "false detections" to reduce dataset and do manual cross-check.





Acknowledgements

- Thanks to NFR and industry partners ConocoPhillips, Lundin, OCTIO, READ and Statoil for financial support of the project
- E. Shalev, IESE and H. Johnson, UiB for help during the installation
- Collaboration with CO2LAB at UNIS





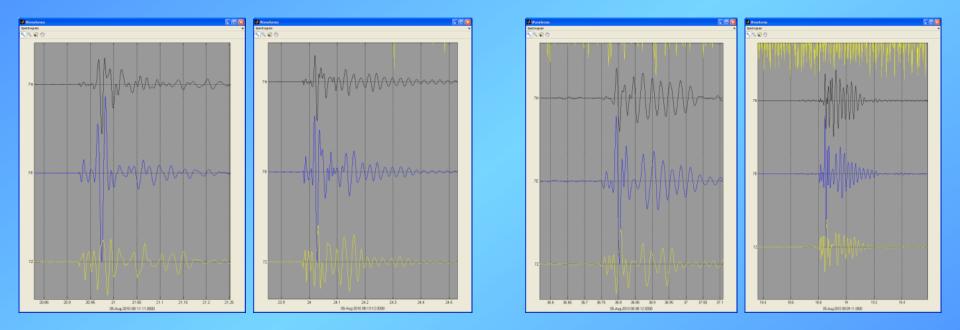








Example of hammer and 'explosion'



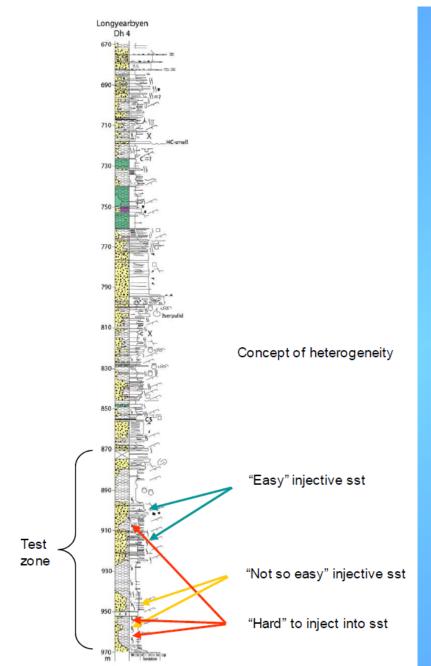
Same site (SH2), with 1 repetition

Explosions

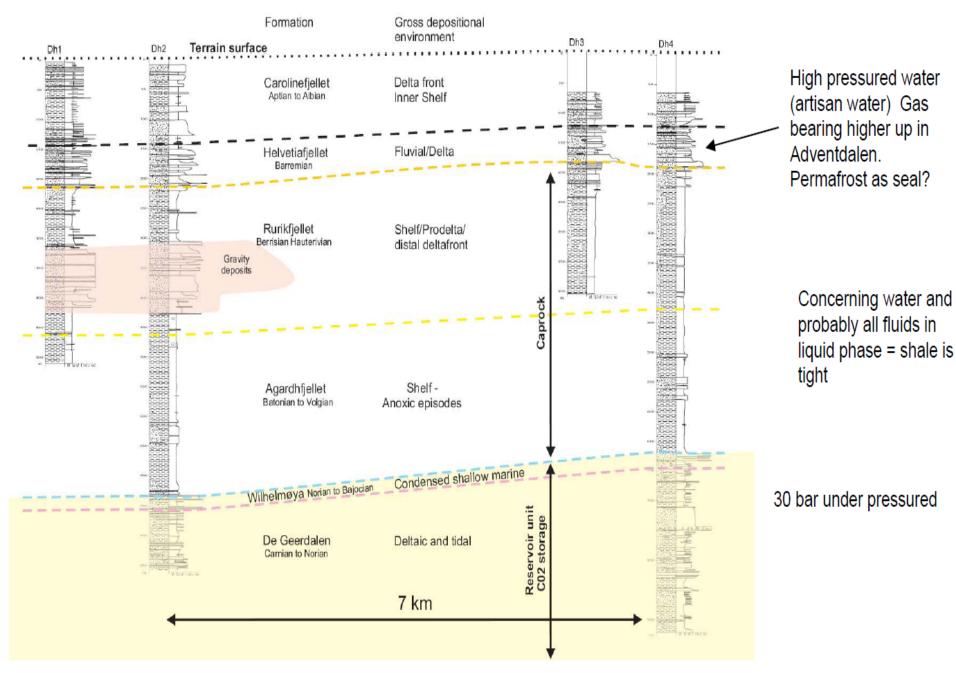
Hammer







Well correlation Adventdalen



NRSAR



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Following minute of data, no cars, different noise pattern on downhole geophones