# How do we best monitor induced seismicity of CCS sites?

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4th Schatzalp Induced Seismicity Workshop Davos, 21. March 2025



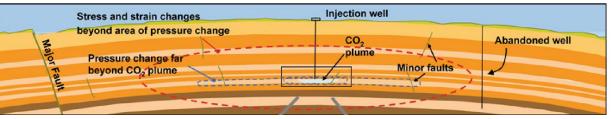
## **Microseismic monitoring of CO<sub>2</sub> storages**

#### Important risk mitigation tool

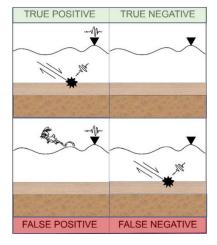
- detect a sufficient number of true microseismic events
- accurately locate events
- appropriately characterise events
- real-time and transparent

#### Success depends on

- network geometry
- sensor type (geophones, DAS, ...)
- processing workflow



Rutqvist, Geotech Geol Eng, 2013

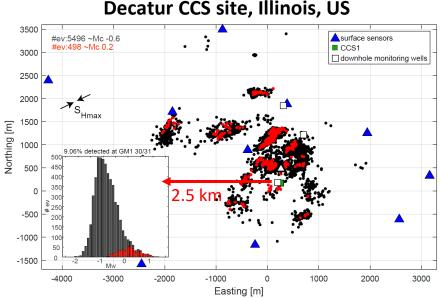




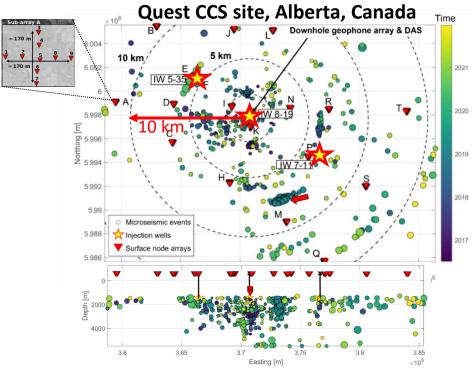
- Downhole geophones close to the reservoir have the best SNR and therefore the lowest detection ٠ threshold.
- At Decatur about 9% of events can be detected with shallow borehole sensors. ٠
- Mc increases towards the surface from -0.6 to +0.2.
- Shallow/surface sensors only allow for a reactive ٠
- Proactive is needed as early-stage diagnostic tool of in response to injection ٠

 $\rightarrow$  detection of potential seal integrity, or well problems, before leakage occurs

 $\rightarrow$  foster public trust

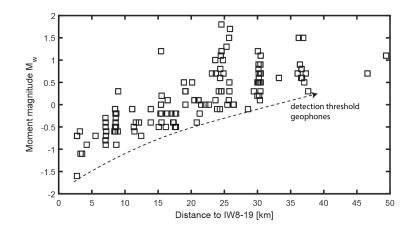




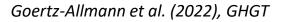


~ 500 events with M -2 to 0.8 located in the Precambrian basement

- Downhole string with 8 3C geophones
- DAS cable within central injector
- Surface arrays with 153 nodes in 17 sub-arrays



- → detection threshold increases with distance from monitoring well
- → to cover entire AOR, surface monitoring becomes more important



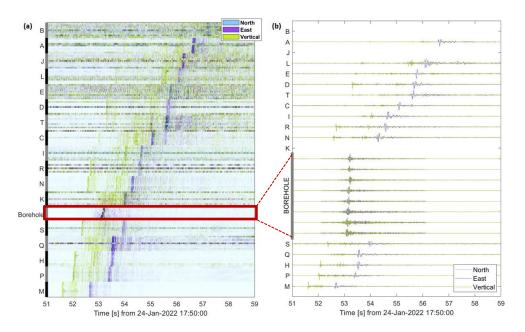
Sub-array A

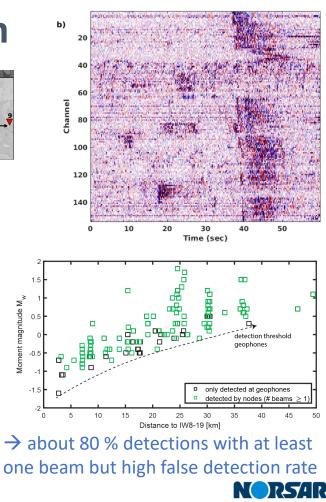
≈ 170 m

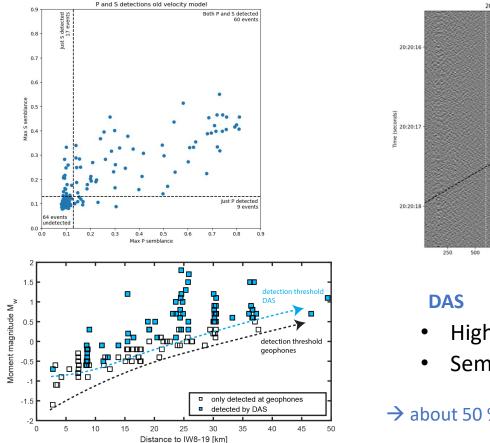
≈ 170 m

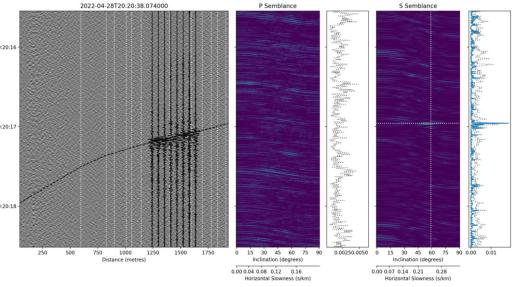
#### Surface nodes

- Lower SNR, but array beamforming to enhance SNR
- Noisy traces can distort beamforming result and advanced pre-processing/ filtering is required.
- Detect events if fk power weighted by noise level is above threshold.









- Higher instrument noise
- Semblance stacking to detect events

ightarrow about 50 % detections with DAS



Baird et al. (2024), EAGE

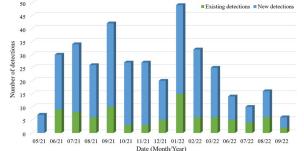
### **Lowering detection threshold**

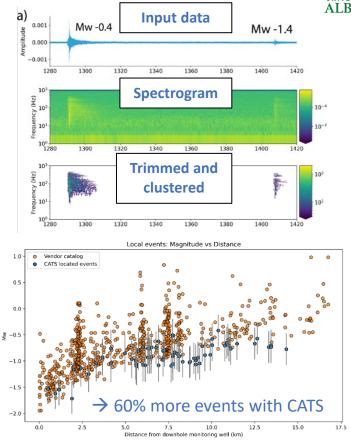
- Cluster Analysis of Trimmed Spectrograms (CATS): detect signals above the noise spectrum by a specified threshold
- Template matching and ML to remove false detections

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 $\rightarrow$  300% increase in event detection but not all can be located

work by Xu Yang



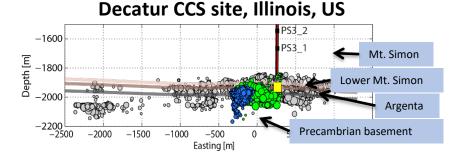


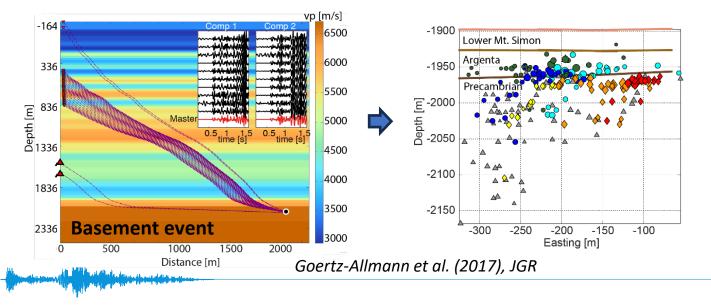
#### Wardah Fadil et al. 2024, GeoConvention



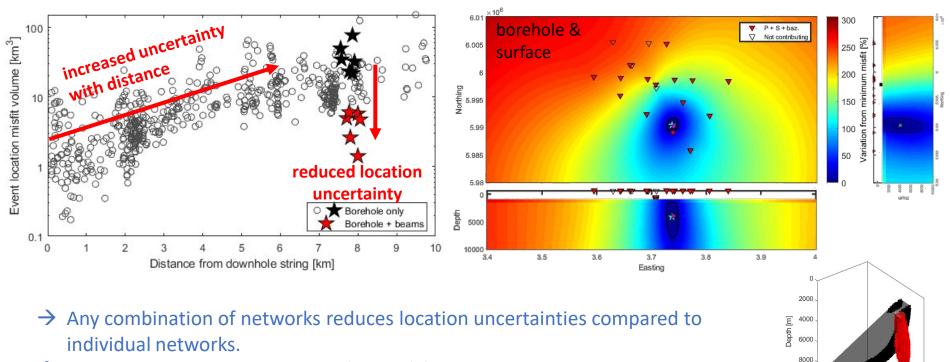
#### **Event locations**

- Reservoirs are generally thinner than depth uncertainty from standard methods.
- Additional constraints need to be exploited to improve depth resolution (e.g., later arrivals / multipathing) but this often requires deep sensors and large vertical aperture.





#### **Event locations**



10000

5996

5994

5002

 $V = 35 \text{ km}^{3}$ 

V = 5.8 km

374

Easting [km]

372

370

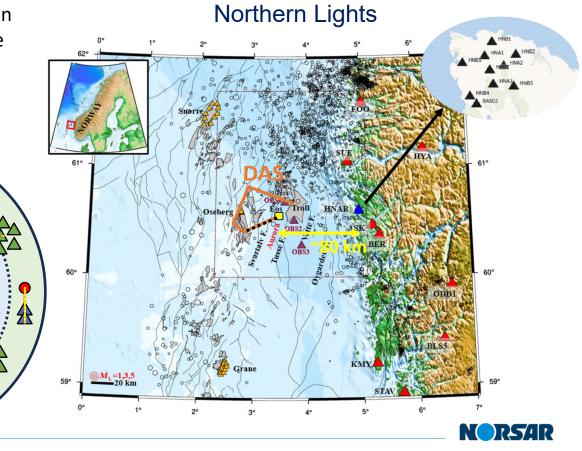
 $\rightarrow$  Still too large depth uncertainty (± 3 km) for unambiguous event association.

#### Goertz-Allmann et al. (2024), IJGGC

#### How do we best monitor induced seismicity of CCS sites?

- Combining different technologies can improve event detection and reduce location uncertainties!
- The more the better?
- Some monitoring is better than no monitoring!

Cost factor!





#### Thank you for your attention!

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