How do we best monitor induced seismicity of CCS sites?

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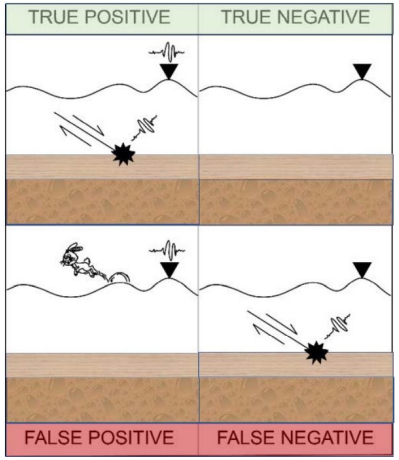
NORSAR
Exploring the Earth

Microseismic monitoring of CO_2 storages

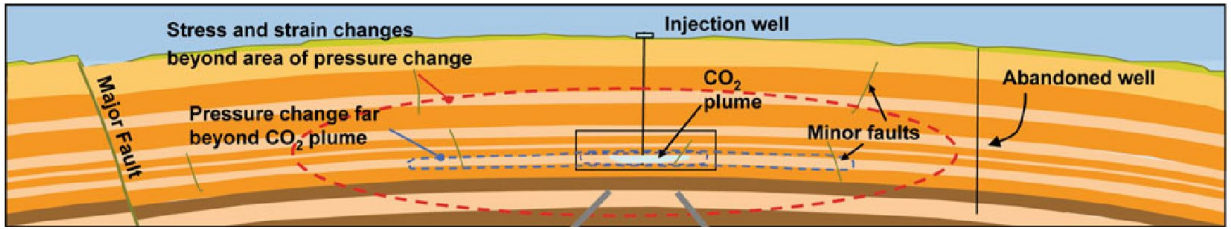
Important risk mitigation tool

- 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

NORSAR

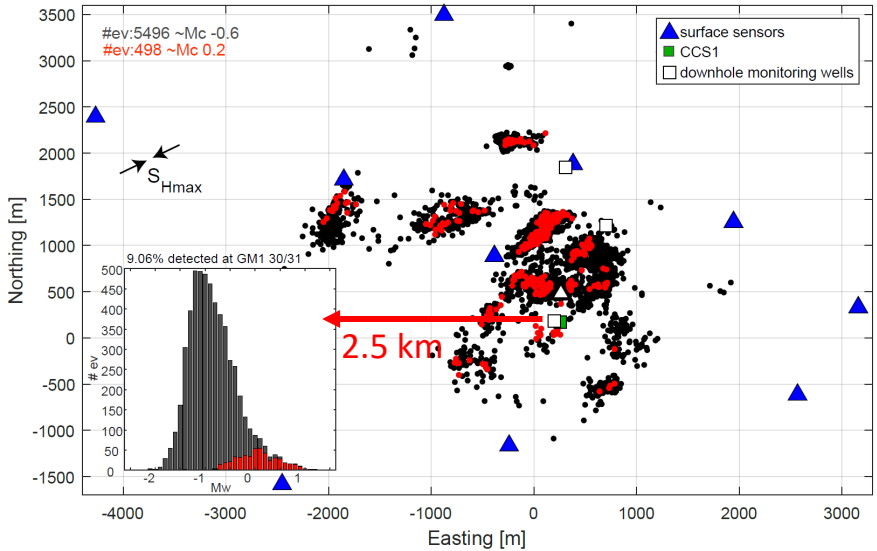
Event detection

- Downhole geophones close to the reservoir have the best SNR and therefore the lowest detection threshold.
- At Decatur about 9% of events can be detected with shallow borehole sensors.
- Mc increases towards the surface from -0.6 to +0.2.
- Shallow/surface sensors only allow for a **reactive** and not **proactive** monitoring.
- Proactive is needed as early-stage diagnostic tool of the reservoir response to injection

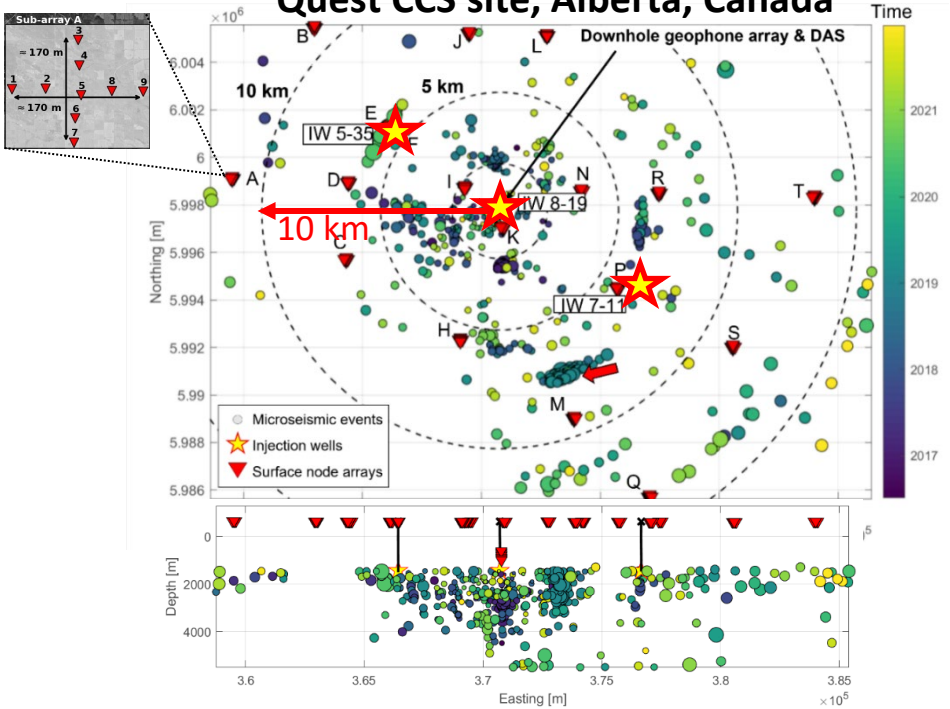
  → detection of potential seal integrity, or well problems, before leakage occurs

  → foster public trust

Decatur CCS site, Illinois, US

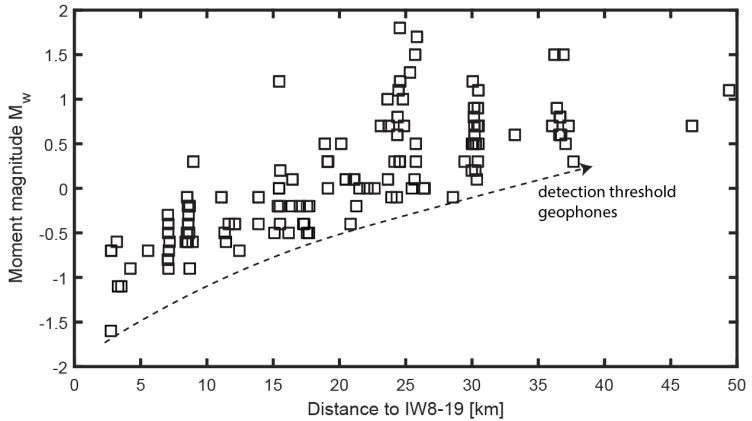


Event detection



~ 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

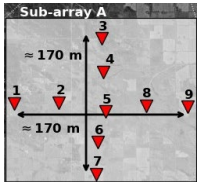
→ to cover entire AOR, surface monitoring becomes more important

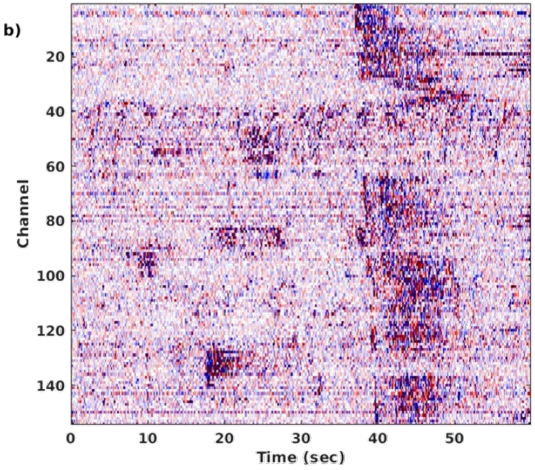
Goertz-Allmann et al. (2022), GHGT

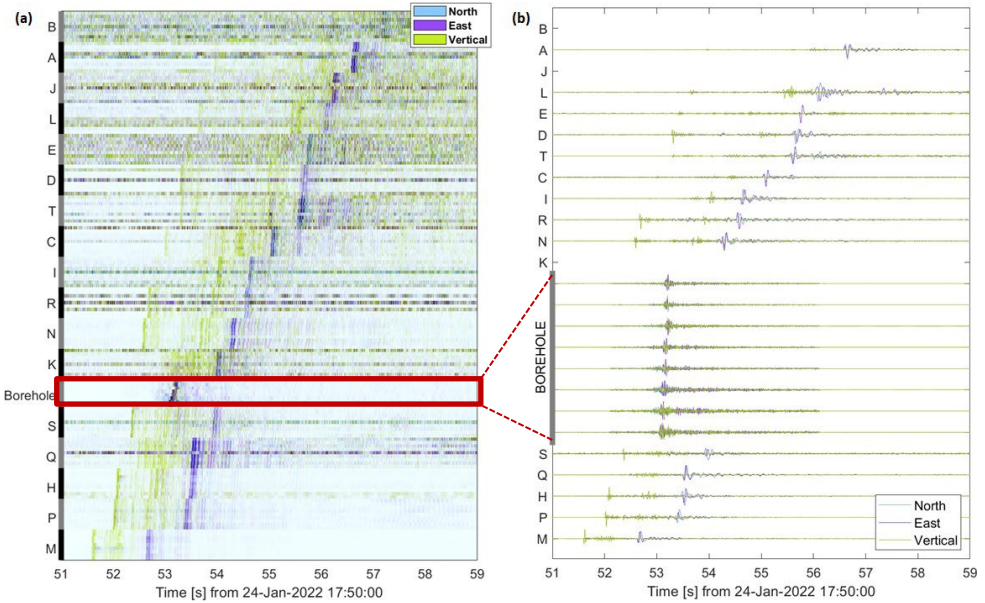
Event detection

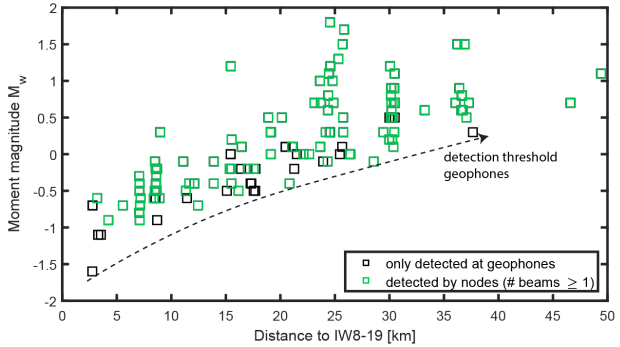
Surface nodes

- 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.



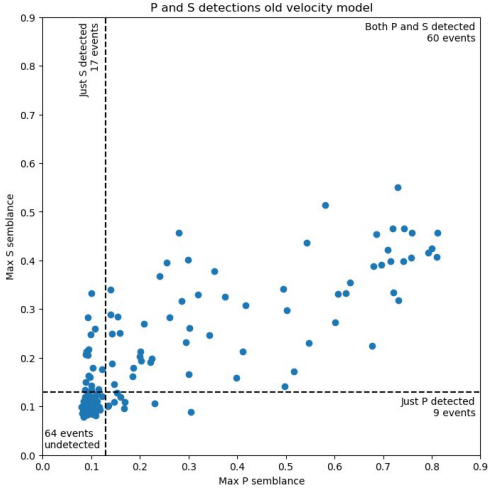


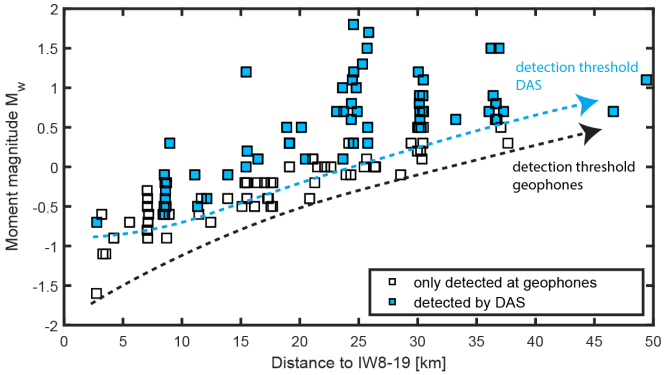


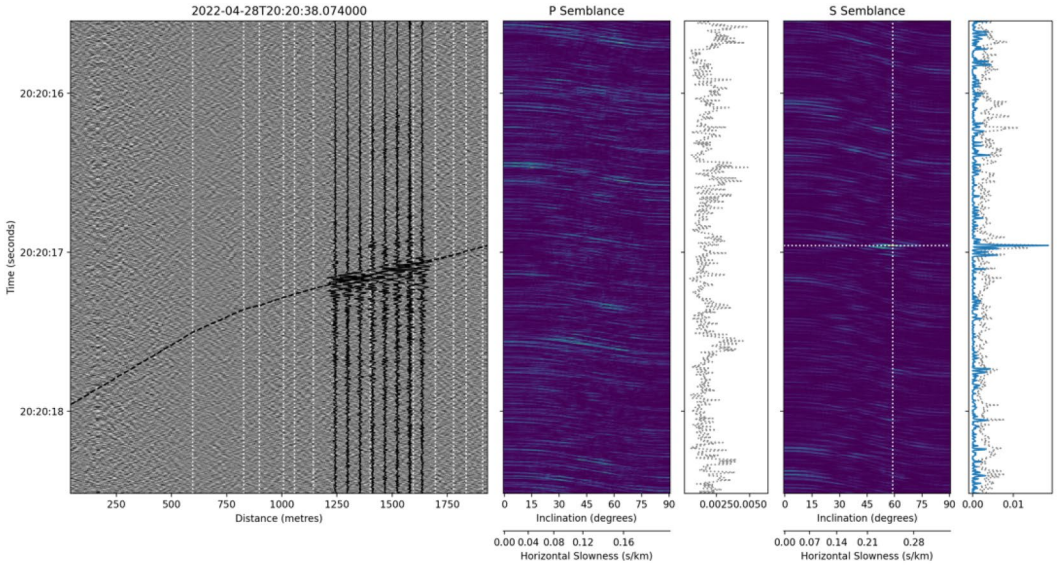


→ about 80 % detections with at least one beam but high false detection rate

Event detection







DAS

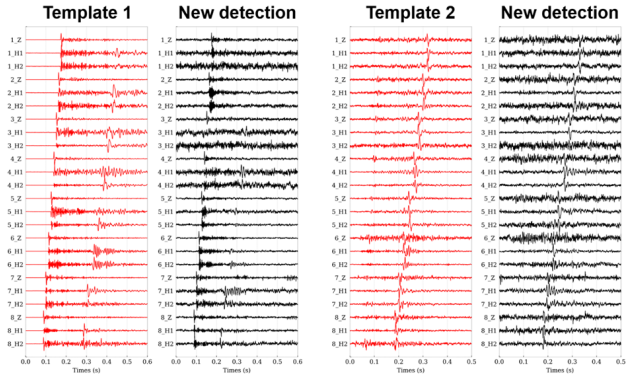
- Higher instrument noise
- Semblance stacking to detect events

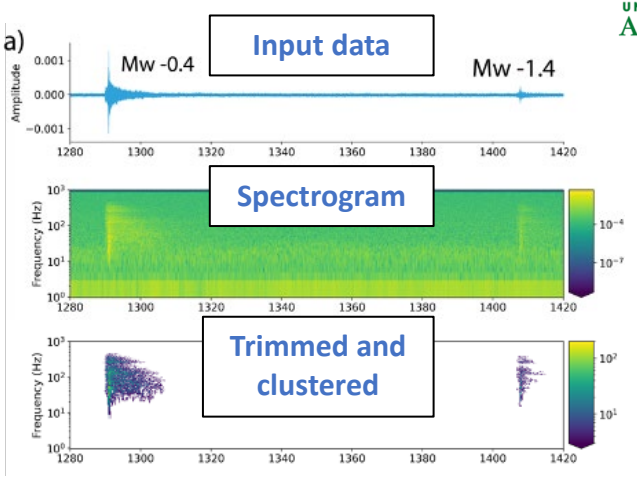
→ about 50 % detections with DAS

Baird et al. (2024), EAGE

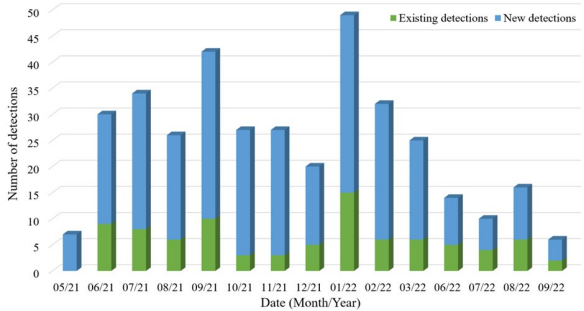
Lowering detection threshold

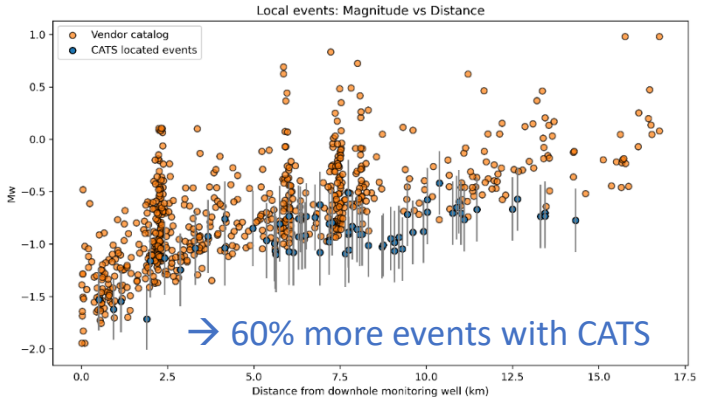
- Cluster Analysis of Trimmed Spectrograms (CATS): detect signals above the noise spectrum by a specified threshold
- Template matching and ML to remove false detections





→ 300% increase in event detection but not all can be located





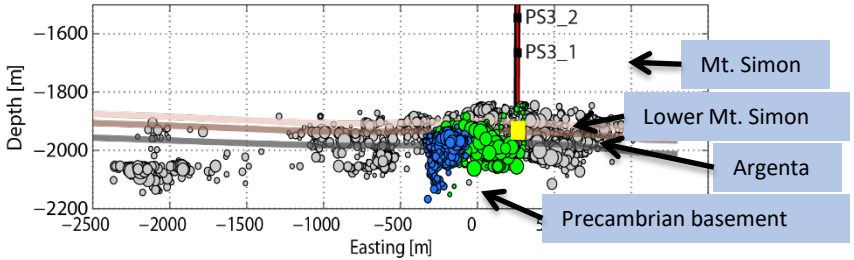
work by Xu Yang

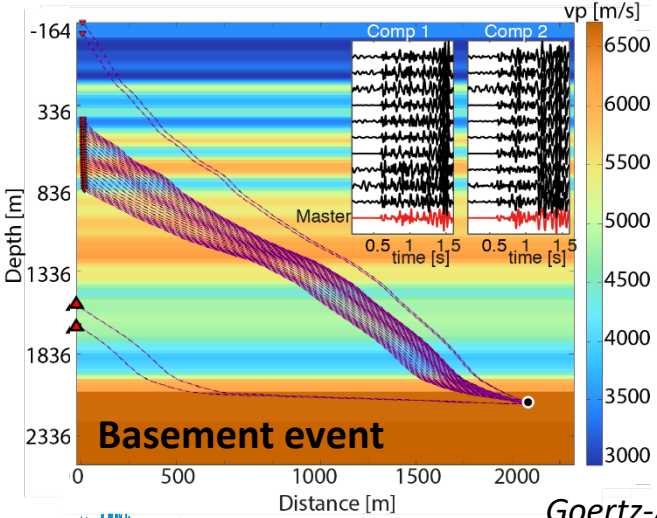
Wardah Fadil et al. 2024, GeoConvention

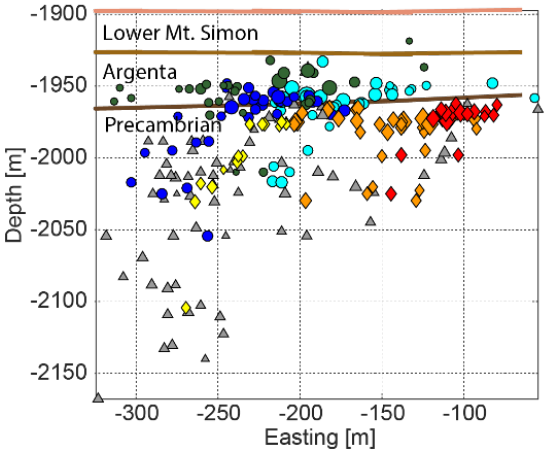
Event locations

- 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.

Decatur CCS site, Illinois, US

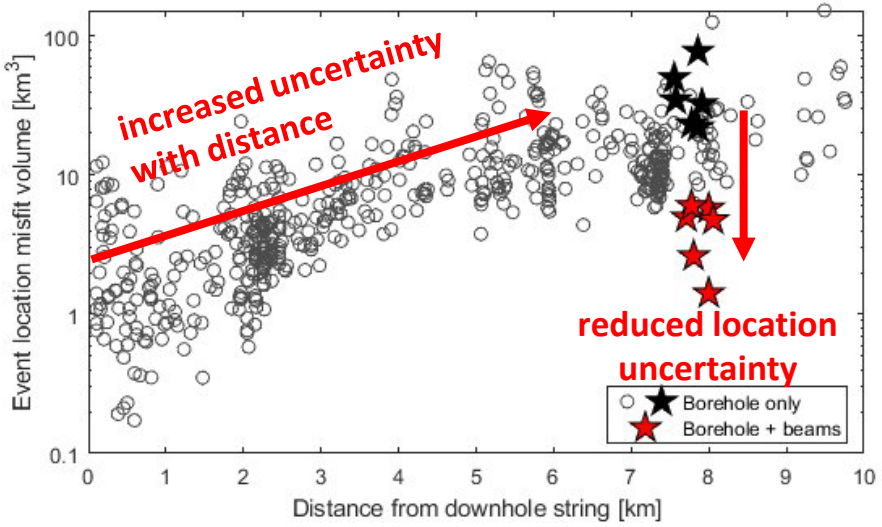


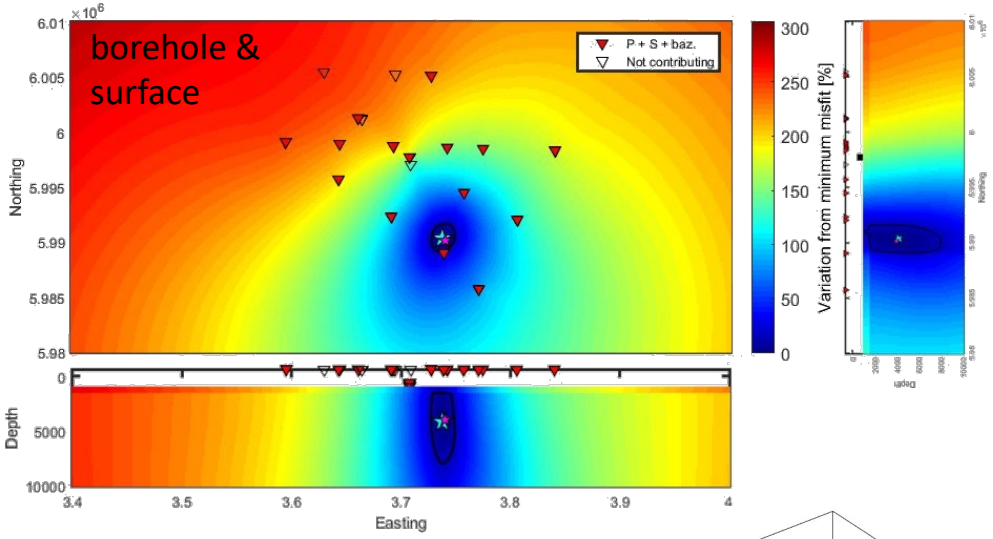


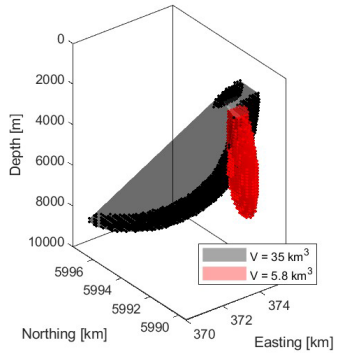


Goertz-Allmann et al. (2017), JGR

Event locations







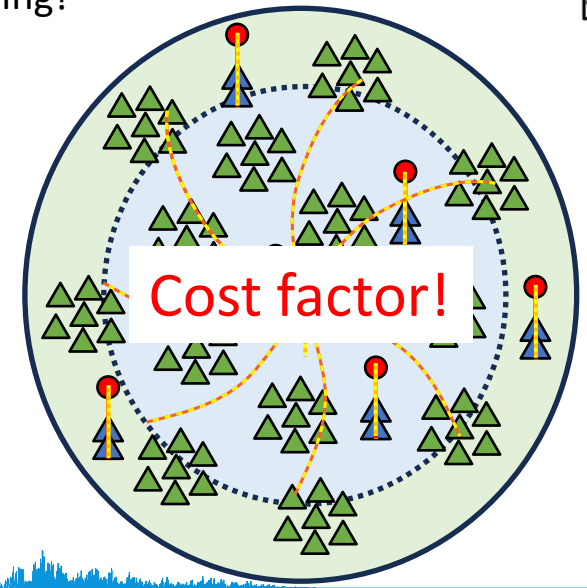
→ Any combination of networks reduces location uncertainties compared to individual networks.

→ Still too large depth uncertainty (± 3 km) for unambiguous event association.

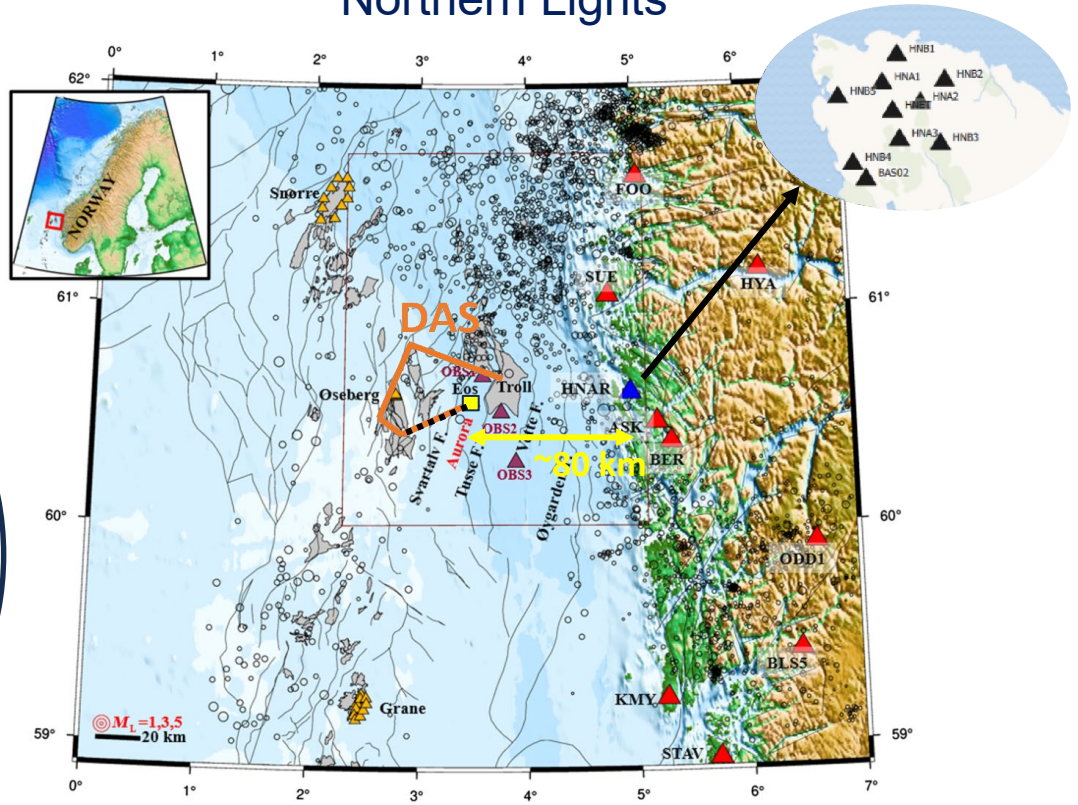
Goertz-Allmann et al. (2024), IJGGC

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!



Northern Lights



Thank you for your attention!

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