Persistent Microseismic Monitoring Using Robust Permanent SADAR Arrays

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INTRODUCTON

Tradition methods of microseismic monitoring, measurement, and verification (MMV) for geologic carbon storage (GCS) utilize (Eaton, 2018):

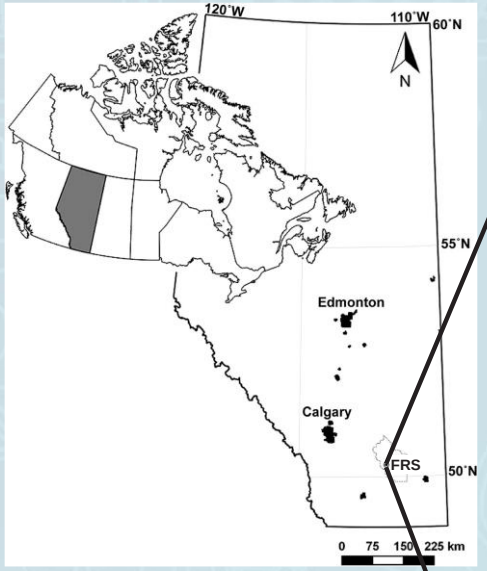
- Networks of surface sensors, covering large areas, and
- Downhole sensor arrays, typically using existing wells to save costs.

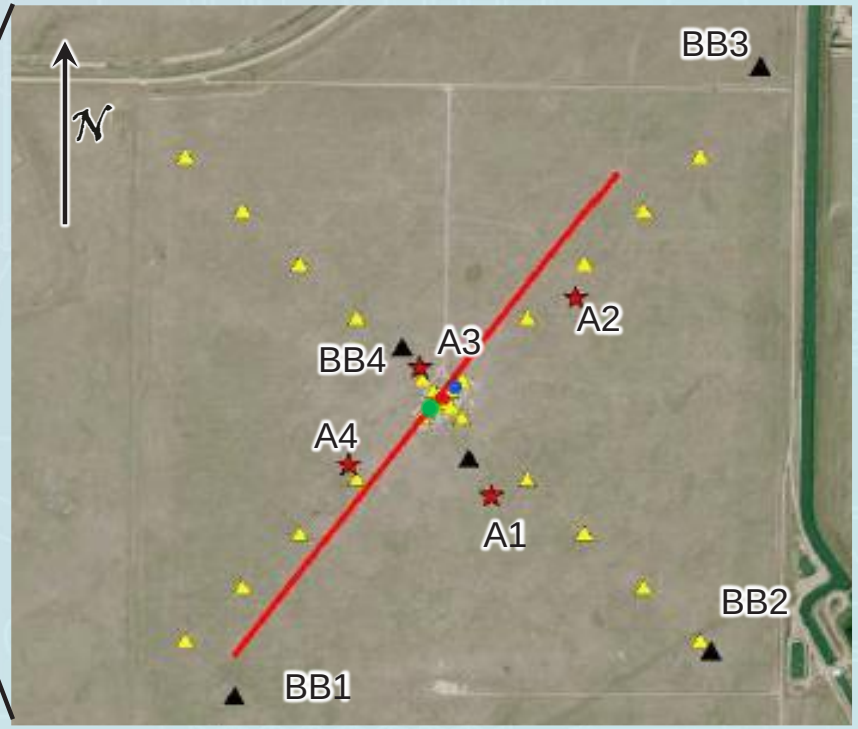
Sparse networks using permanently emplaced compact volumetric phased arrays (SADAR):

- Provide superior data and information,
- Resulting in more precisely locating lower magnitude events,
- Robust to sensor attrition for long term deployment,
- Dual use for passive and active source monitoring, and
- Smaller footprint

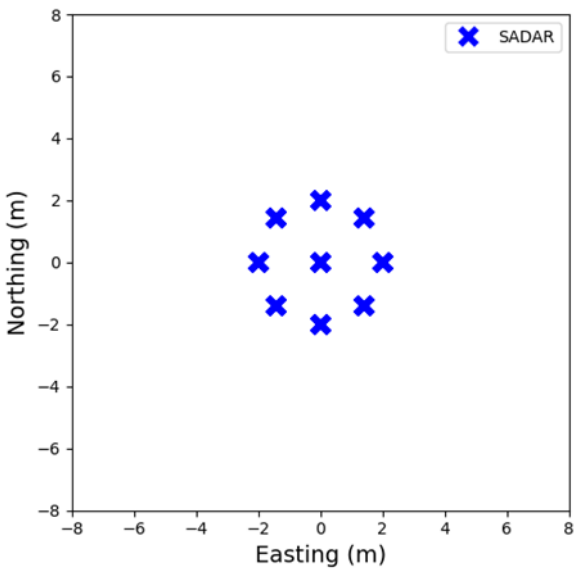
BACKGROUND

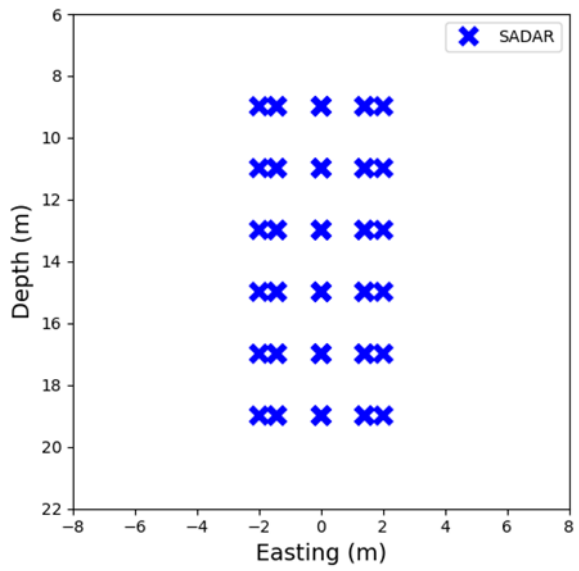
Containment and Monitoring Institute (CaMI) of Carbon Management Canada (CMC) operates a Field Research Station (FRS) in Newell County of southern Alberta, Canada.





- Geochemistry Well – Obs #1 - DAS
- Geochemistry Well – Obs #2 –DAS, 3C phones
- Injection Well
- SADAR array
- 1m deep trench – DAS
- Broadband Seismometers
- Permanent 3C Geophones @ surface

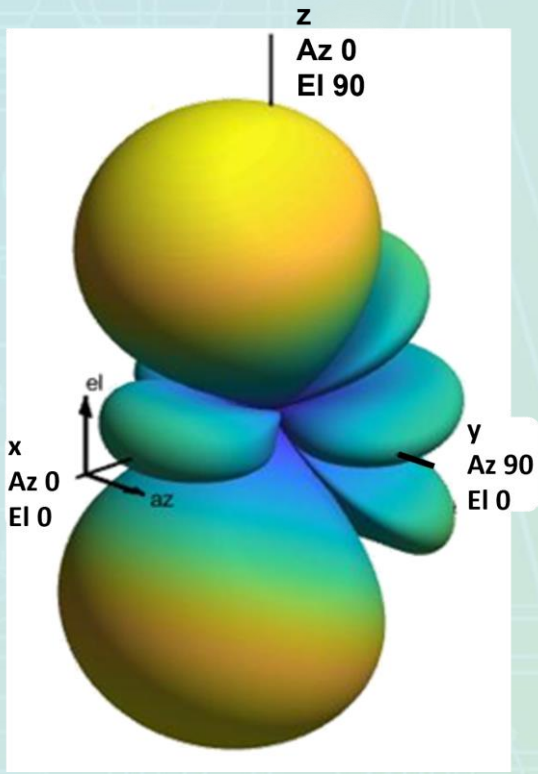


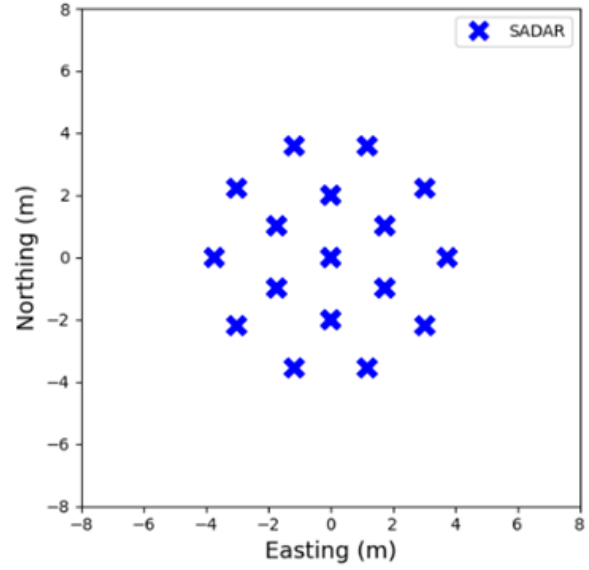


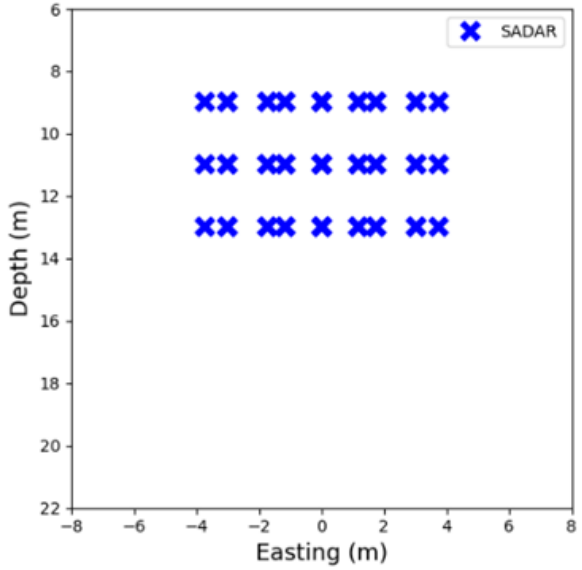
Standard Array:
9 holes, 6 layers

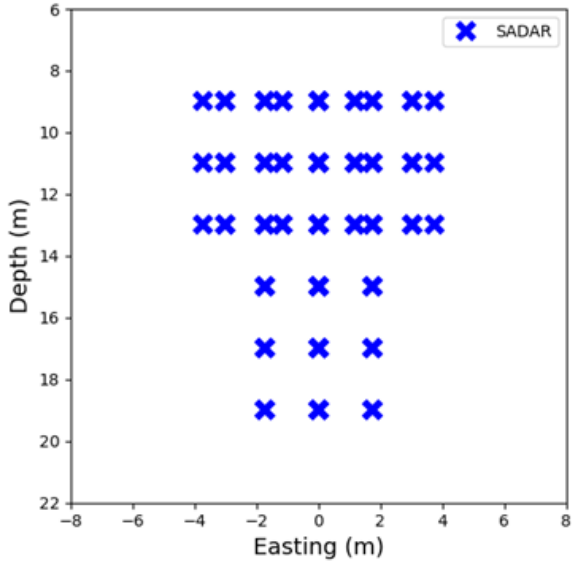
DESIGN

Depth: 9 m – 19 m









Wide Aperture (middle) and Hybrid (right):
17 holes
3 and 6 layers

Layout

Drill (4” hole), grout, push sensor strings into hole

3 sensors per string; 2 strings taped together; bottom sensor installed in a metal cage to push sensor string down the hole.

Geospace GS-ONE 10 Hz vertical phones

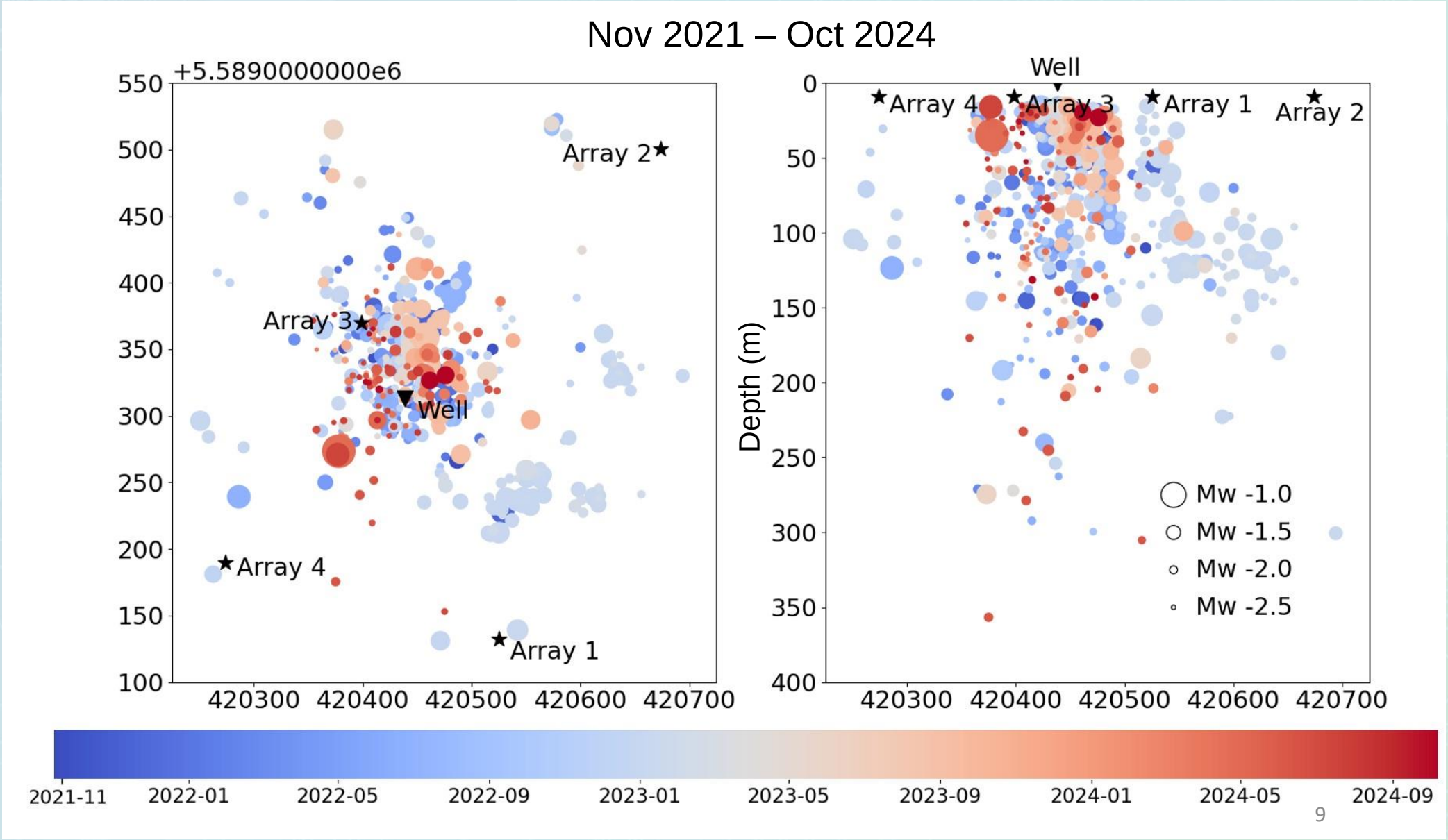
Buried all cables. Digitizers go in an in-ground vault to service if needed. Geospace S-8 DAQs.

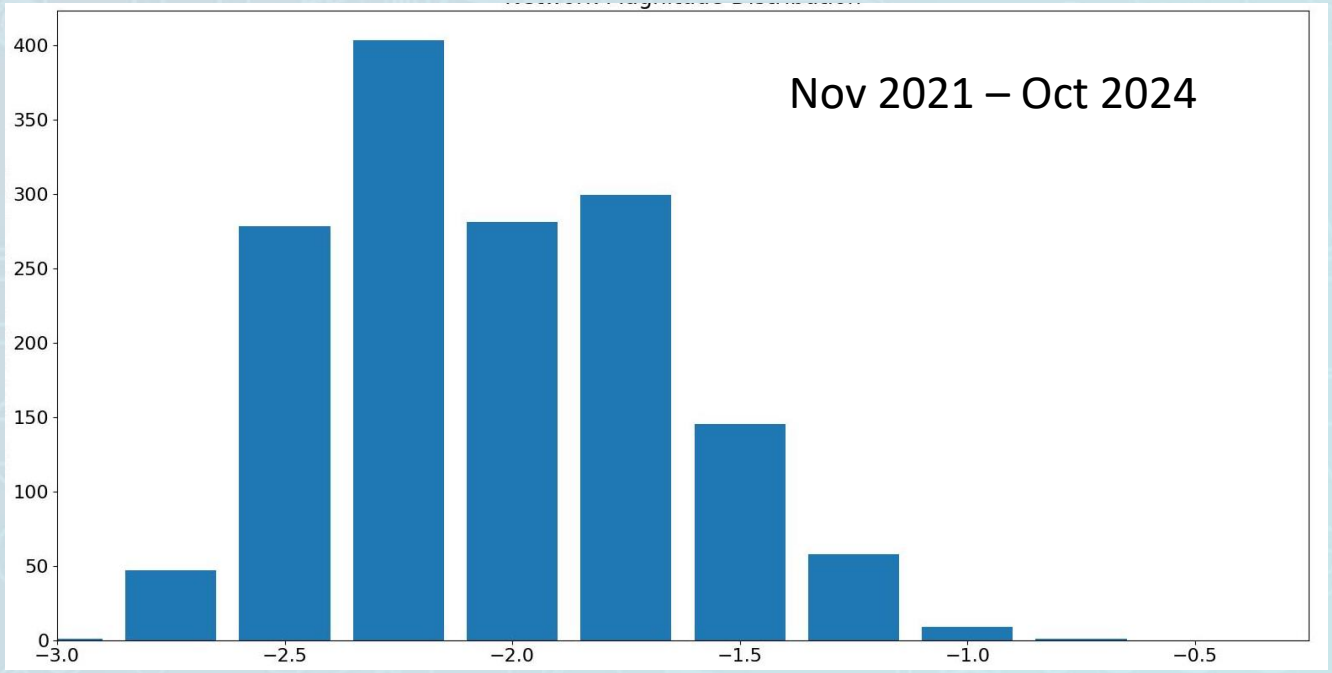
Results

36 months of monitoring:

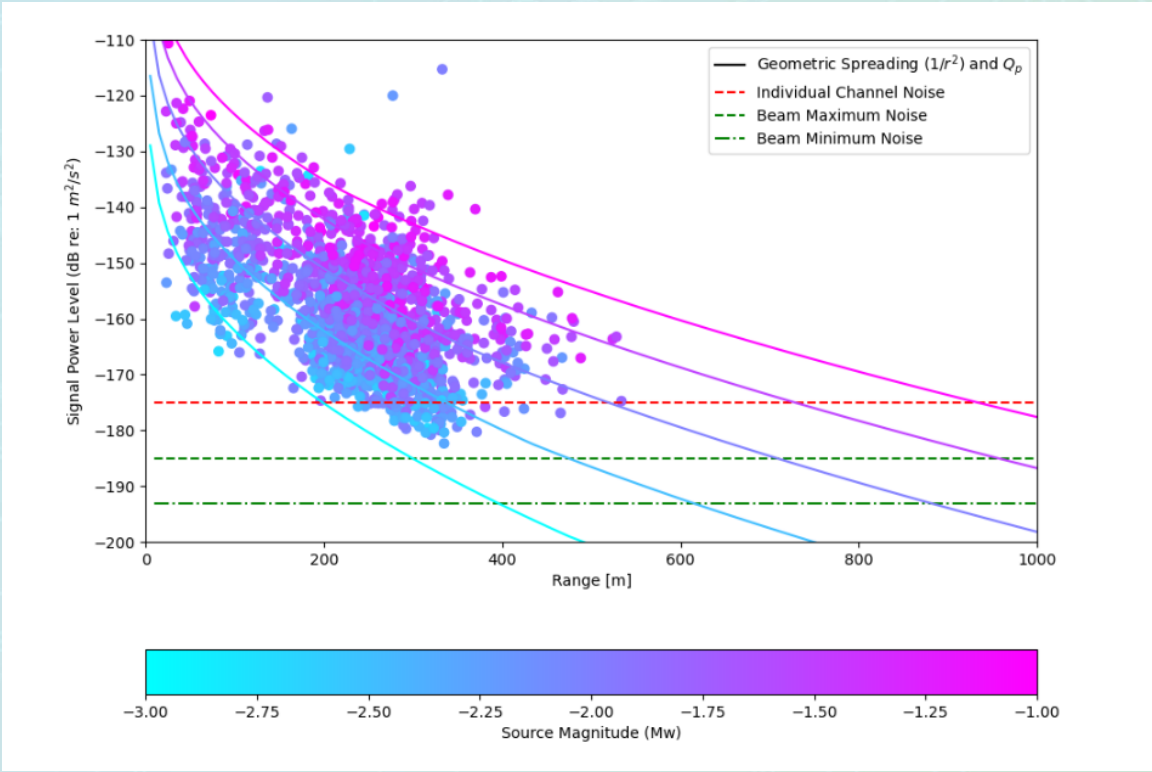
1522 events with Z > 15 m with 4 array locations

9878 events with surface events



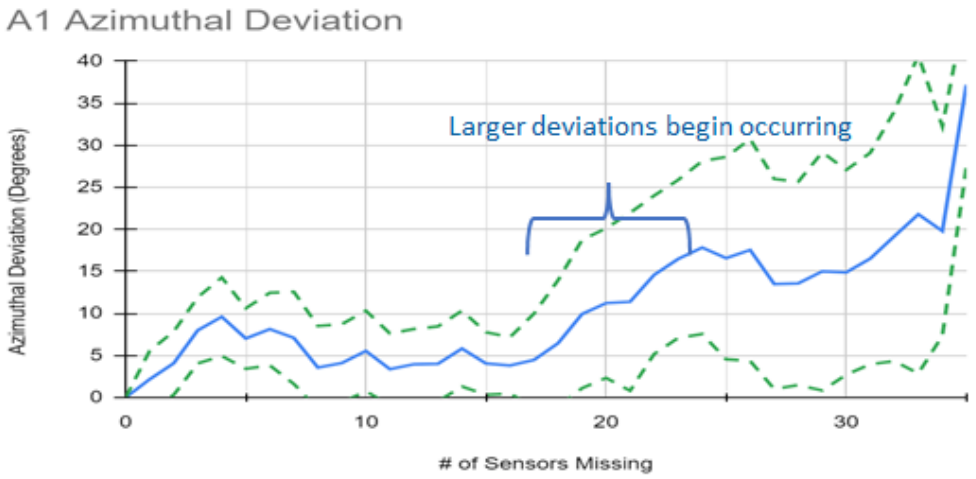


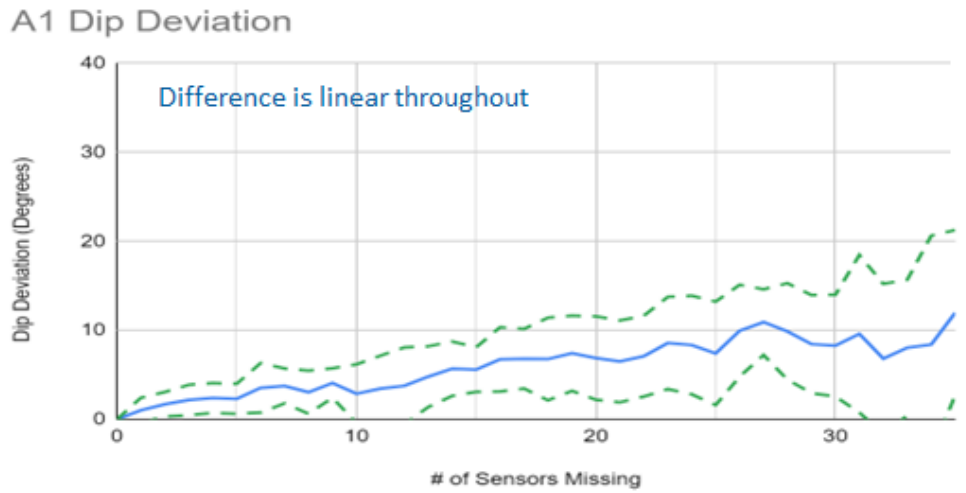
Mw (Brune 1970, 1971) distribution for the 3-yr period.

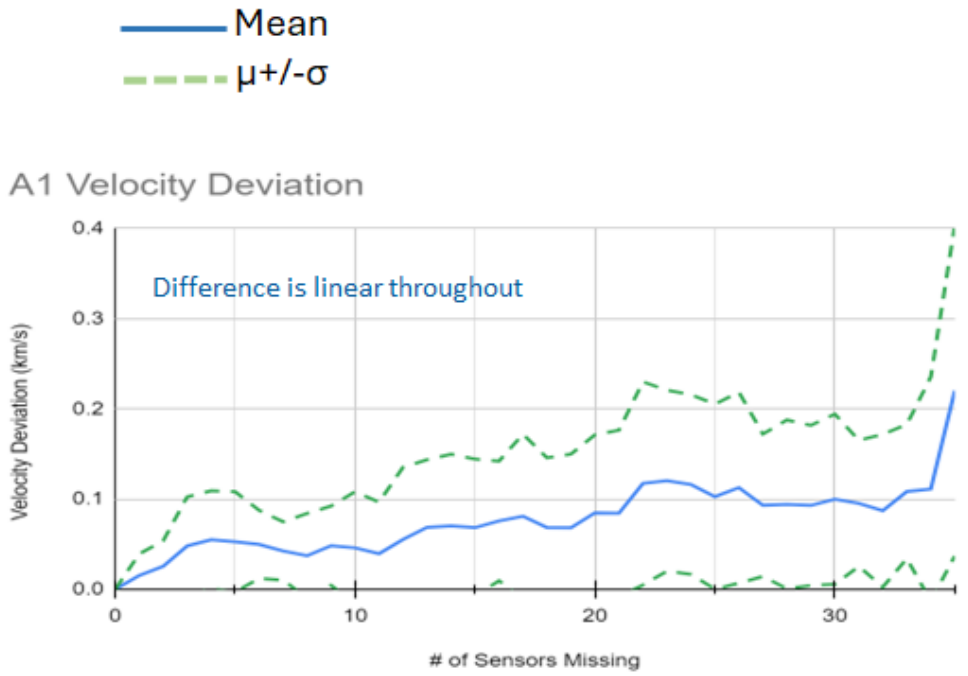


Signal power vs. source-receiver range, 412 well-located events color coded by Mw. Events from Nov 2021 to Oct 2023, with z > 10 m. Signal levels are solid lines adjusted for propagation loss.

ROBUST



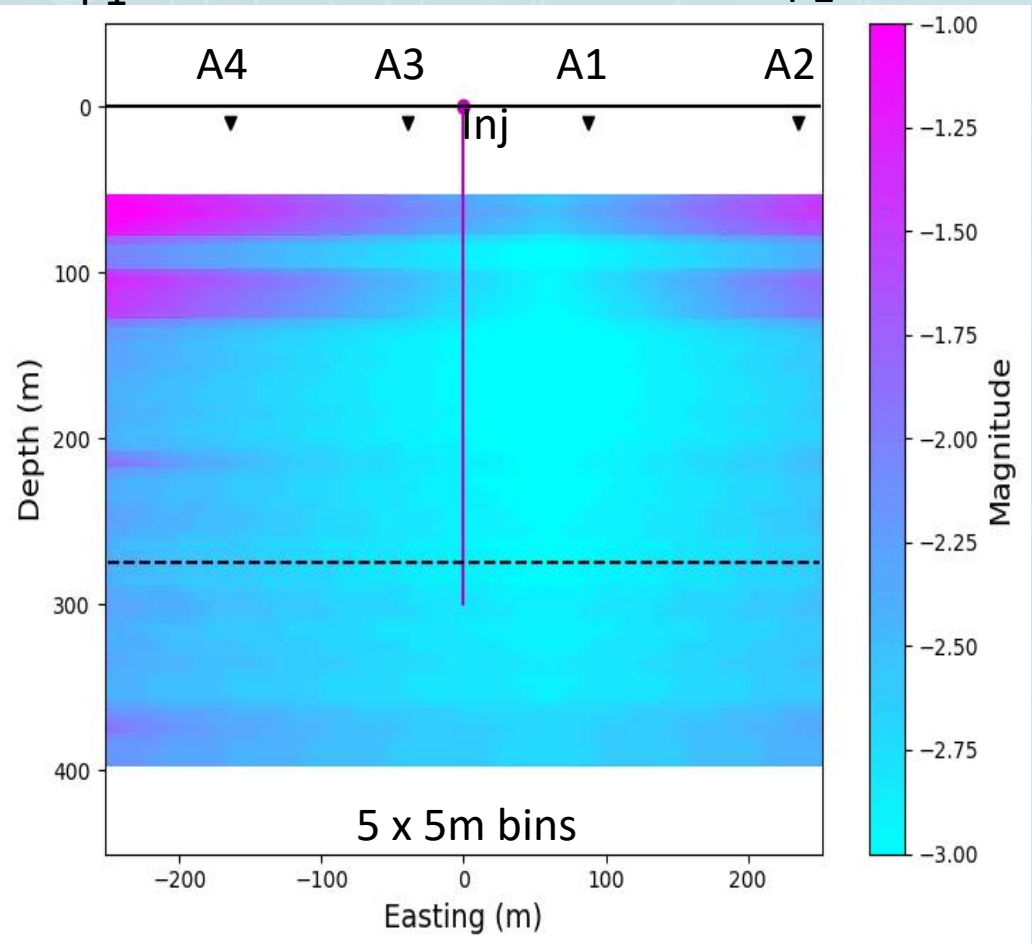




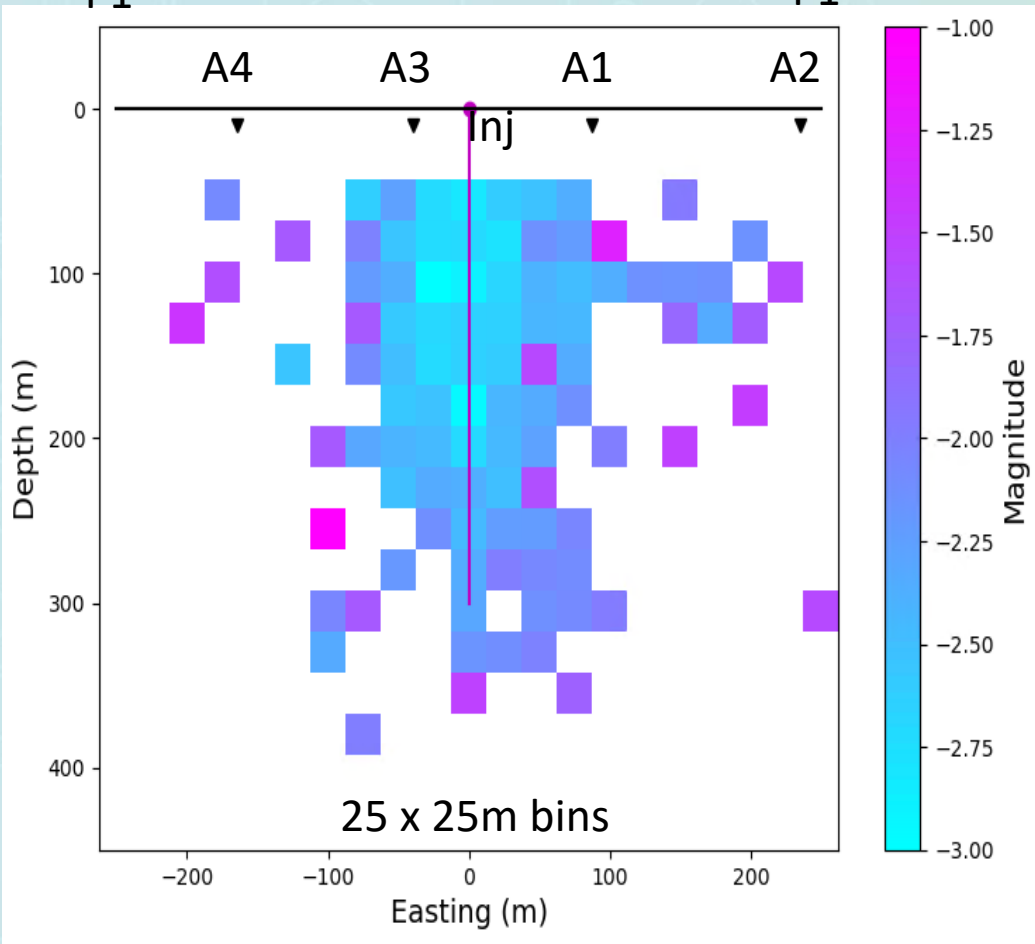
Array robustness: statistically determined from an average of 10 trials of each value of n sensors missing

Performance Model vs. Observed

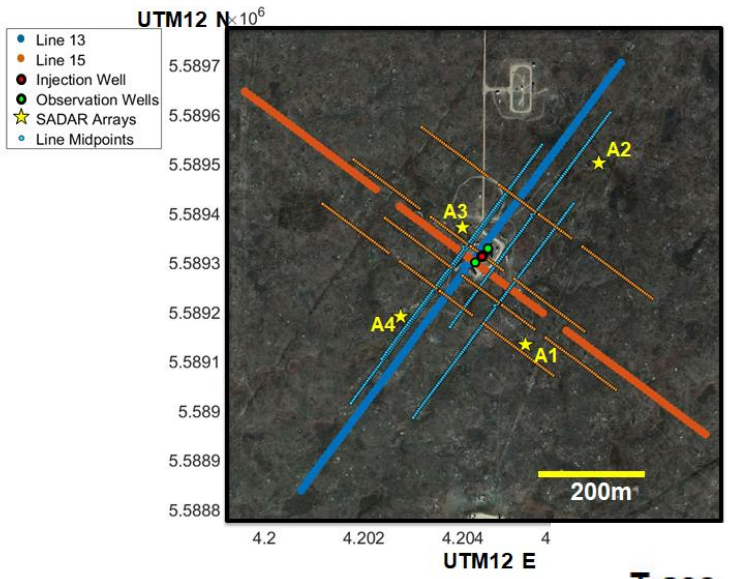
Modelled Minimum Detectable Magnitude (Network)
Profile through Northing = 0m



Observed Minimum Magnitude (Network)
Profile through Northing = 0m



Site provides the data to both calculate network performance from measured attributes, then compare the model with the observed data.

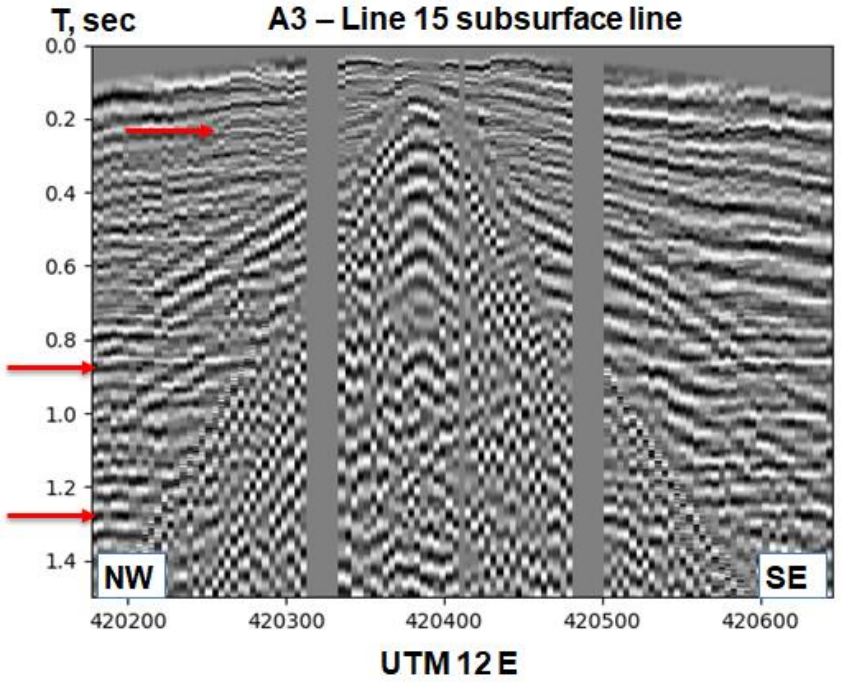


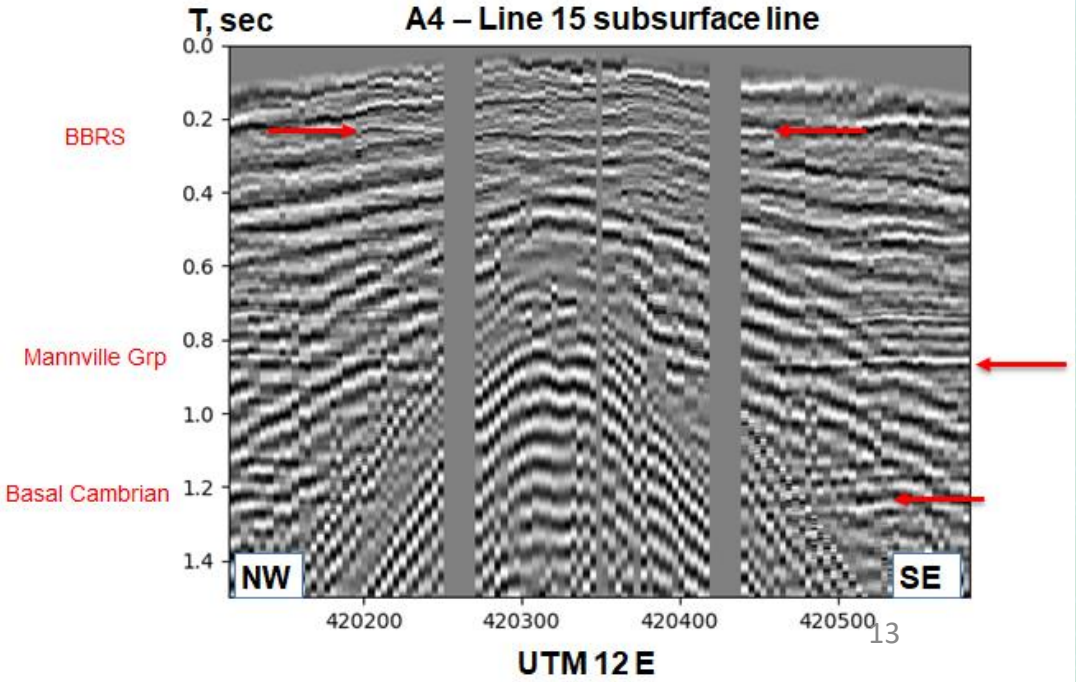
Two vibroseis lines: line 13 (NE-SW, and line 15 (NW-SE), as the thick blue and red lines, with the midpoint sections for each respective array (thin lines).

Vibroseis truck

Conventional reflection seismic processing sequence with beamforming to a specific depth.

Major strata highlighted.





CONCLUSIONS

- Four (4) arrays installed in 7-8 days…working.
- Small footprint: four arrays occupy ~150 m^2.
- Operating at 98.7%; no down time for maintenance:
  - Robustness has been statistically explored with respect to sensor attrition.
- Burial reduces surface noise, increases signal-to-noise.
- Results demonstrate the passive and active capabilities of the SADAR arrays.
- To date, created human vetted bulletin with location, uncertainty, but with other attributes.
- A SADAR array provides lower magnitude thresholds, -2.75 < Mw < -0.75.

WHAT'S NEXT

- Continue passive monitoring at site.
- Repeated active surveys over time are easily achievable.
- Exploring fixed source, fixed receiver path with CMC.

See Poster CCUS 4186259, Quigley et al. for more complete analysis of the active imaging results.

ACKNOWLEDGEMENTS

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