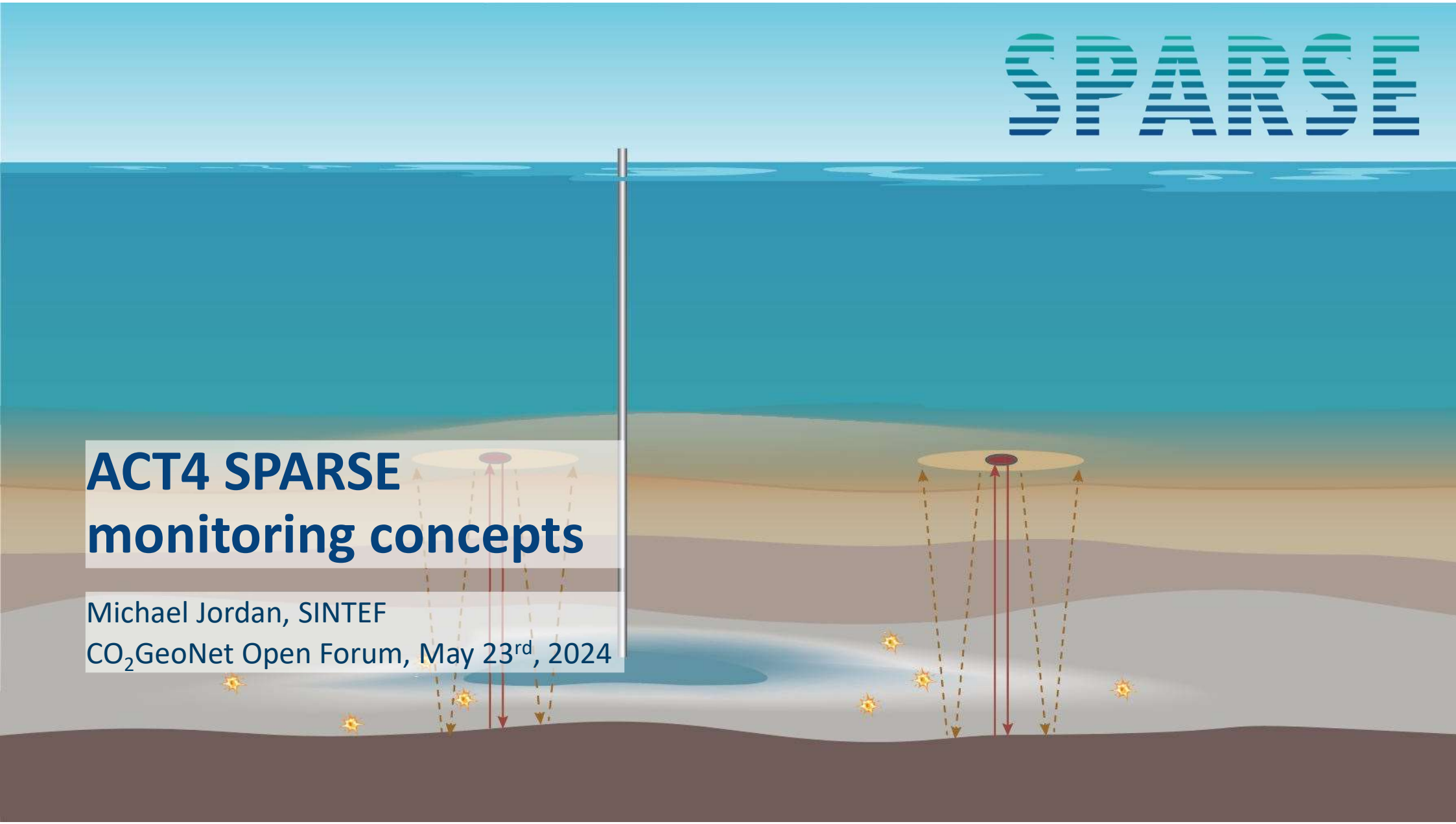


ACT4 SPARSE monitoring concepts

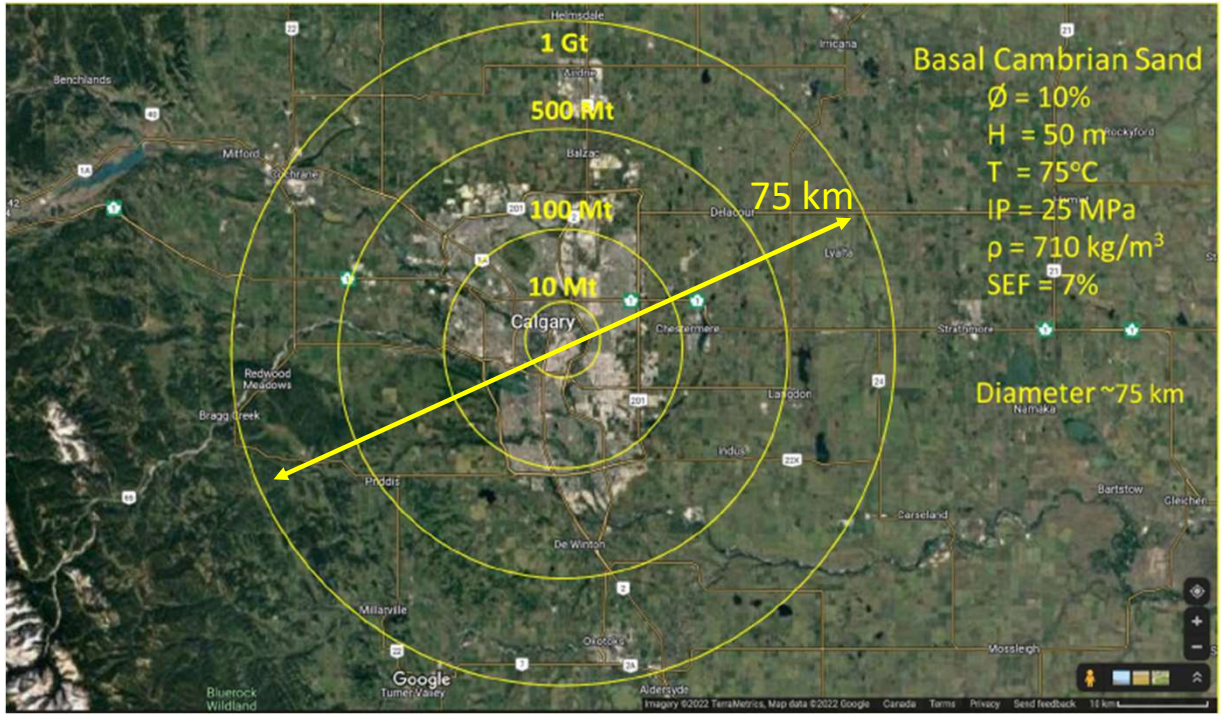
Michael Jordan, SINTEF

CO_2GeoNet Open Forum, May 23rd, 2024

Gigatonne storage & sparse monitoring

- Cost of geophysical monitoring is major challenge for large-scale CO_2 storage
- Conventional 2D and 3D surface seismic monitoring costly, even impractical at GT CO2 storage scales
- Monitoring required during operative phase and long after the injection has ended

Subsurface CO_2 plume size schematic

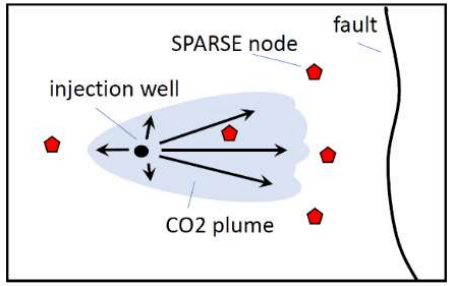


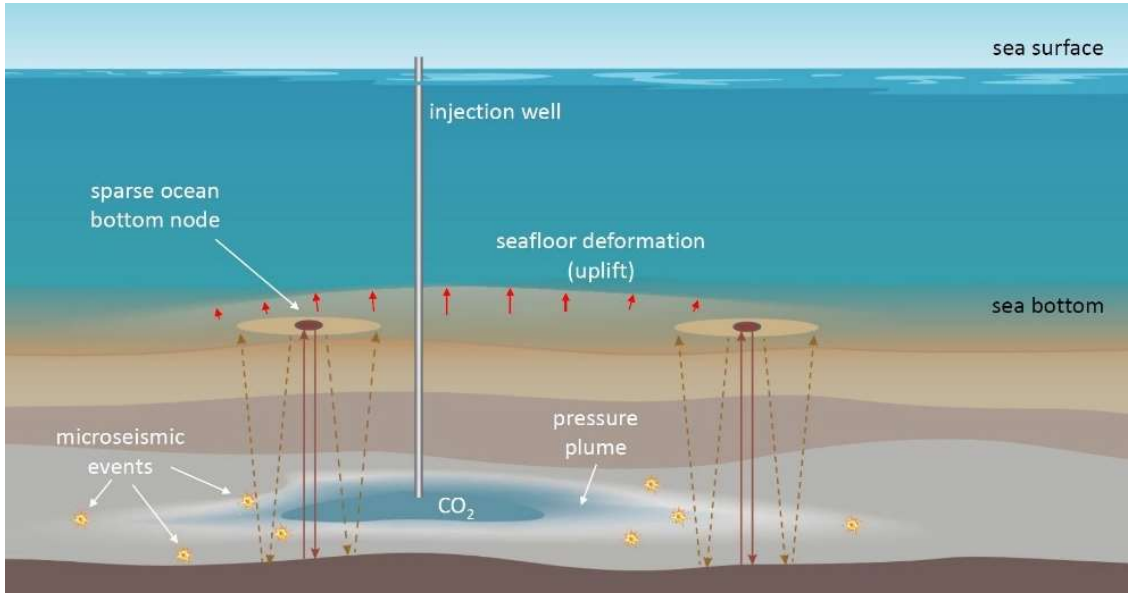
courtesy of Don Lawton

ACT4 SPARSE:

Sparse Passive-Active Reservoir monitoring using Seismic, Electromagnetics, gravity, and surface deformation

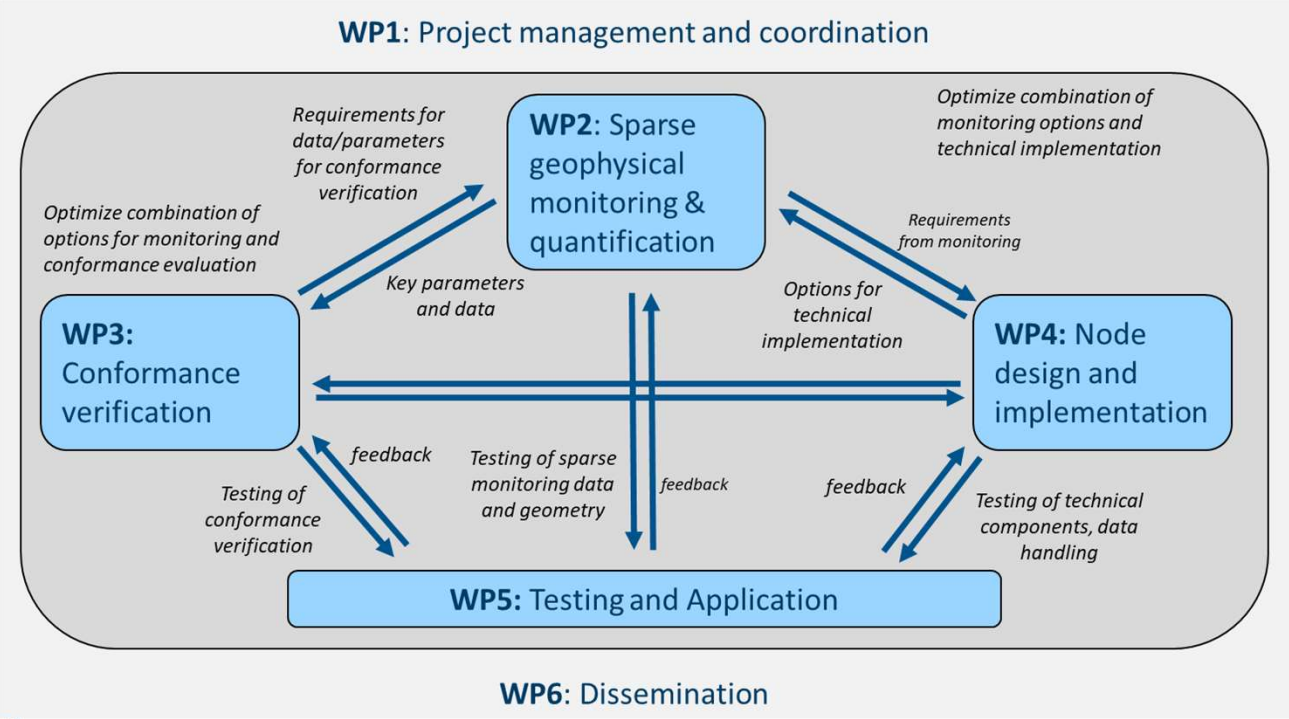
- Aim: Establish reliable long-term, low-cost geophysical MMV to facilitate GT CO_2 storage
- Sparse node-based monitoring
  - Highly repeatable geophysical data
  - Strategically distributed nodes
- Background monitoring to establish conformance and containment
- Trigger target-oriented active seismic surveys if/when/where needed





SPARSE main activities

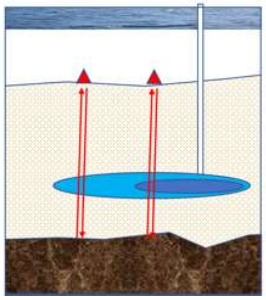
- Establish principal node design
  - "Toolbox" and workflow
  - Low-cost & practical
- Optimum geophysical(WP2) monitoring for sparse-nodes
- Quantify key parameters for conformance (WP2&3)
- Technical realization (WP4)
  - Design & implementation
  - Automatization (ML)
- Test at different scales/sites (WP5)



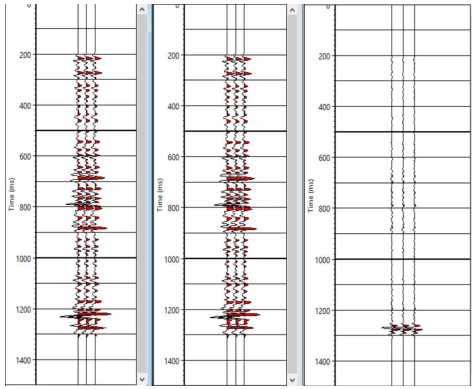
Requires full integration and optimization of all components during the design process!

Examples of potential SPARSE active monitoring

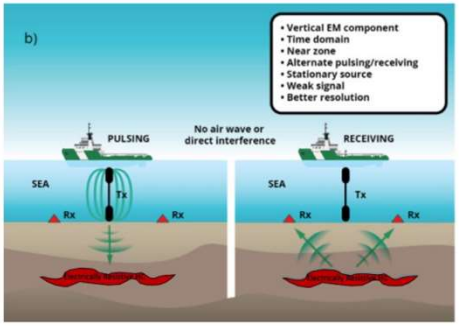
- Offshore



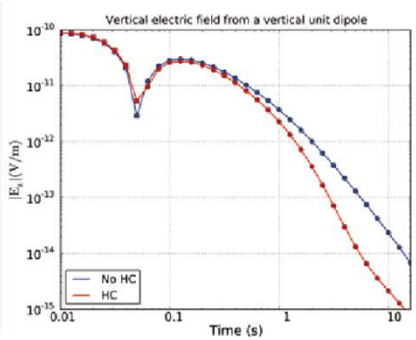
Baseline Monitor Difference



Lawton et al., 2024

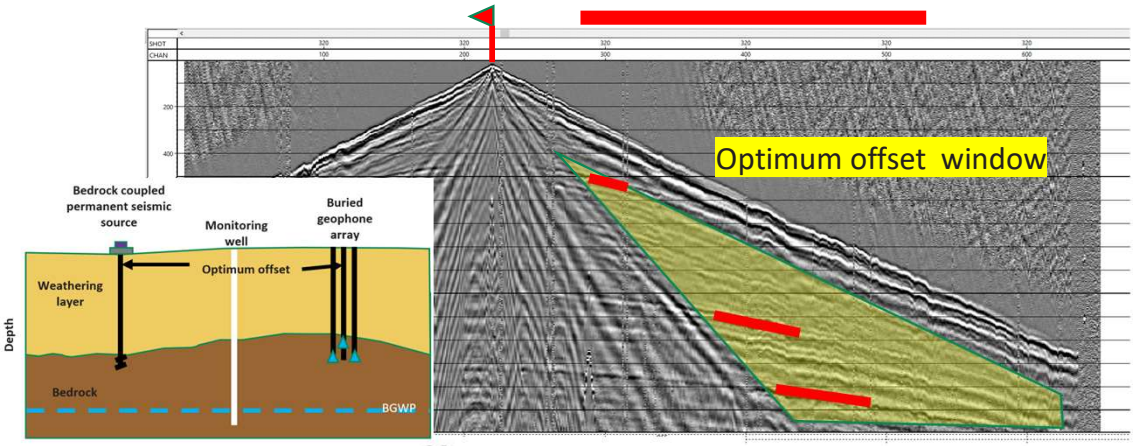


Allton website (https://allton.com/csem/

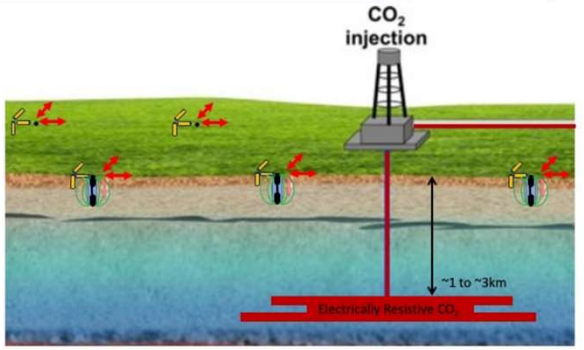


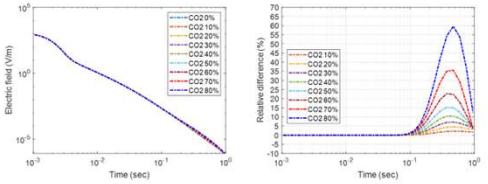
Holten et. al, 2009

- On shore



Lawton et al., 2023





Possible Components of Vertical Source (VS) CSEM Nodal System

Vertical TEM source with electrodes at top and bottom of shallow (~50m to 200m deep) water well

Two-component (x and y) electric field measurements

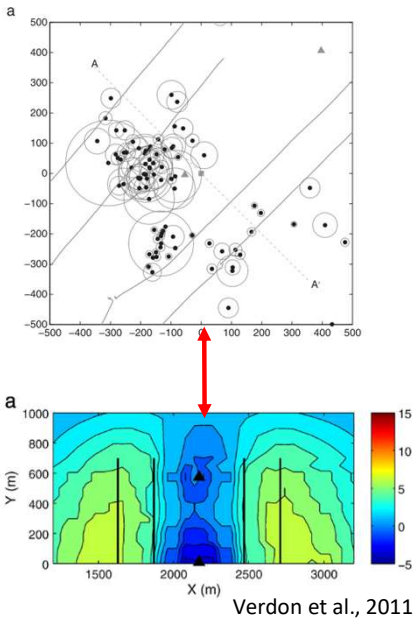
Possible vertical electric field measurements in shallow (~10m to 50m) well

Three component magnetic (B) field or dB/dt measurements

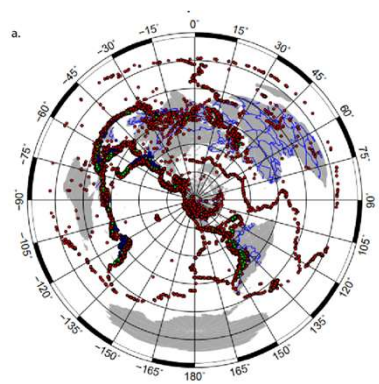
Alumbaugh et al., 2024

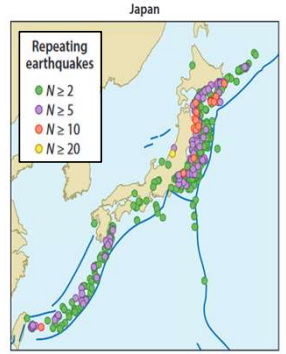
Examples of potential passive SPARSE monitoring

- Passive seismic
  - Microseismic to teleseismic
  - Data from CaMI.FRS and Aquistore, Canada
- Gravity
  - E.g., Sleipner
- Surface deformation
  - E.g., In Salah

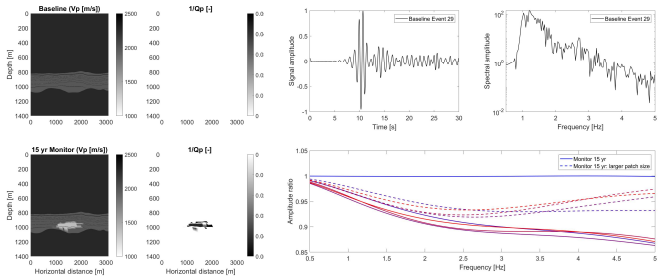


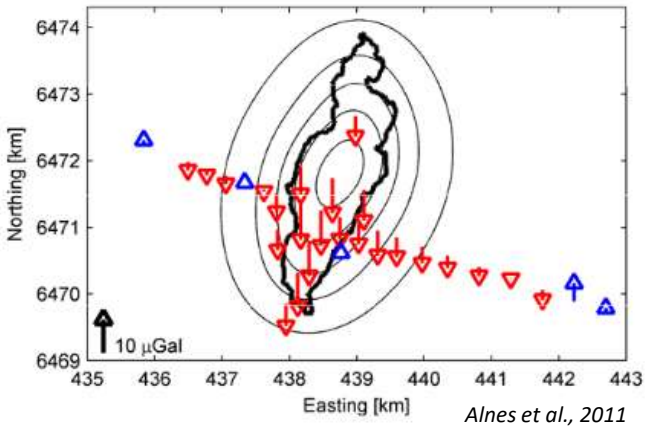
Verdon et al., 2011



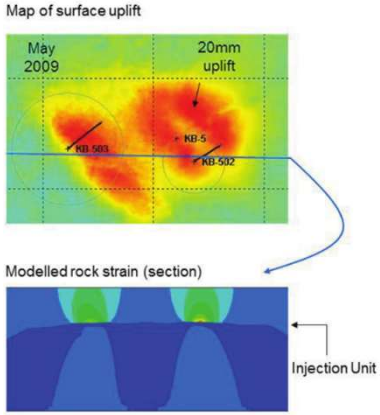


adapted from Igarashi, 2010





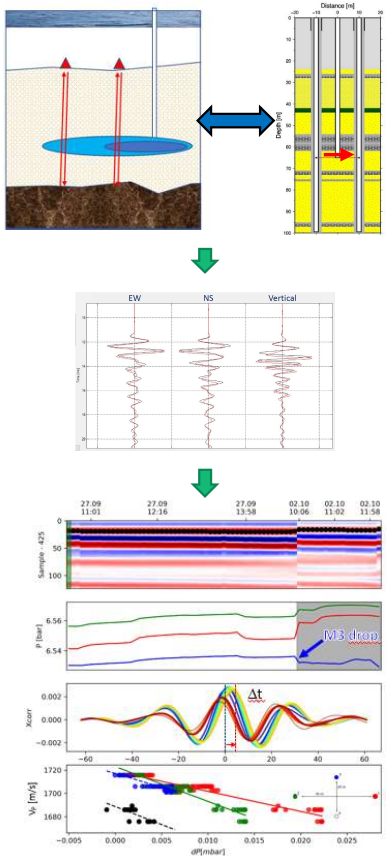
Alnes et al., 2011



Ringrose et al., 2013

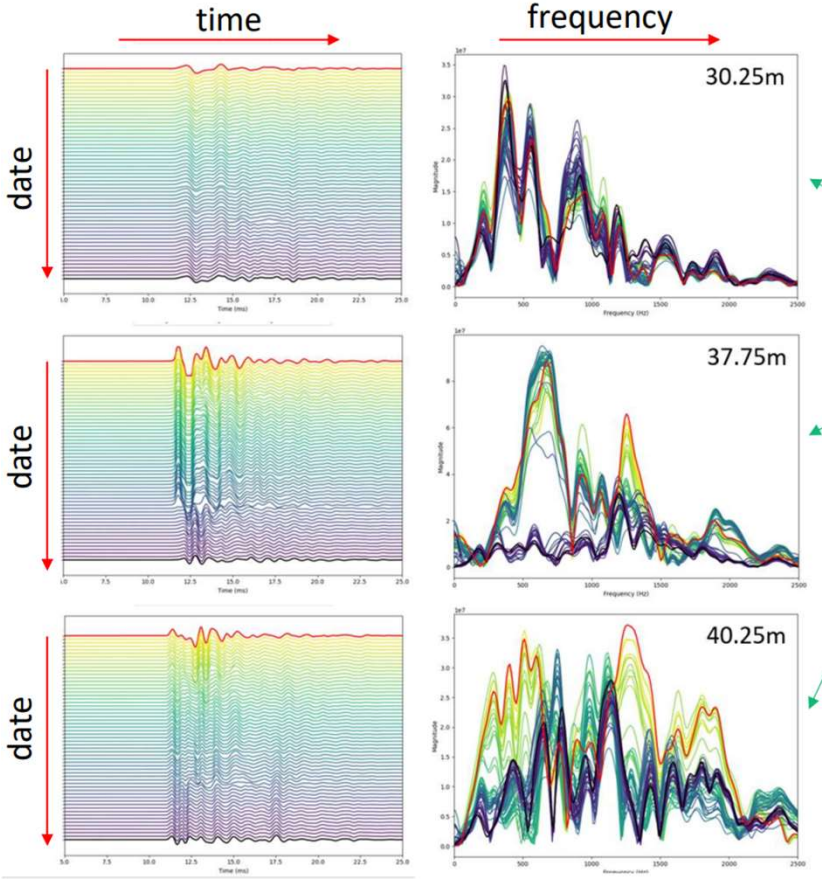
Data exploitation at Svelvik CO_2 Field Lab

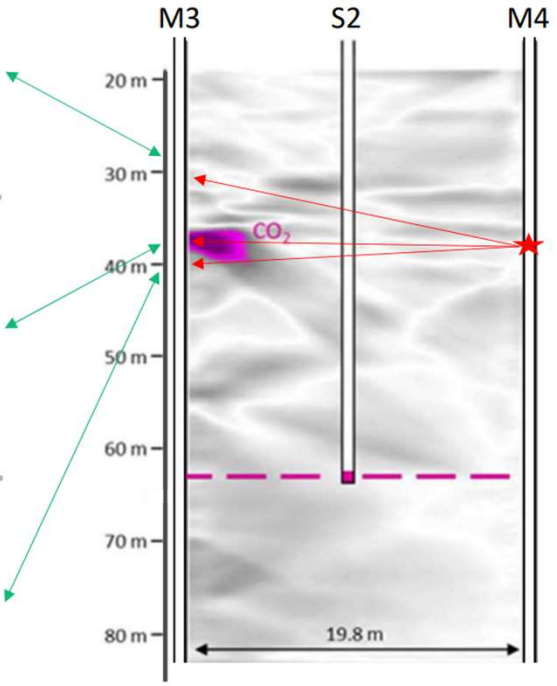
Pressure quantification



Weinzierl et al., 2019

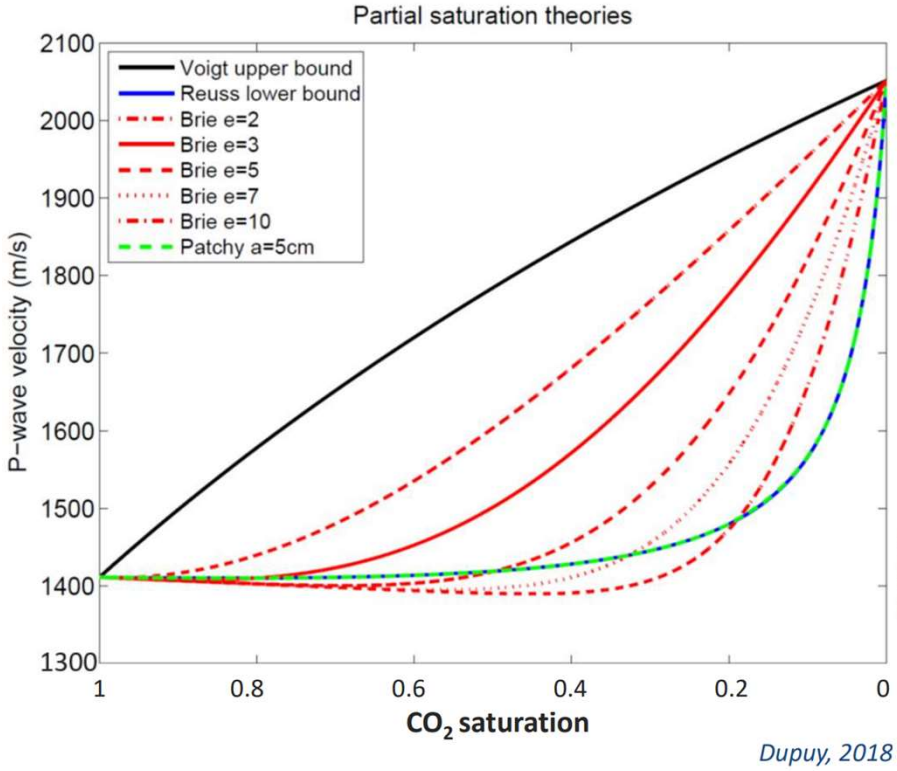
Explore saturation effects on seismic data

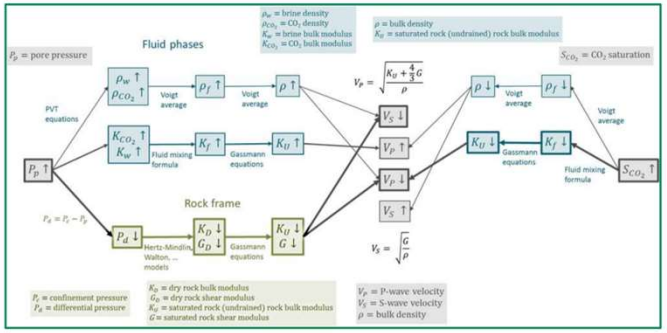


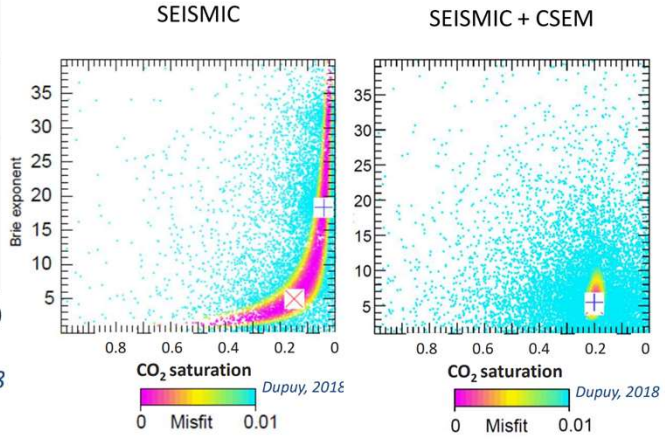


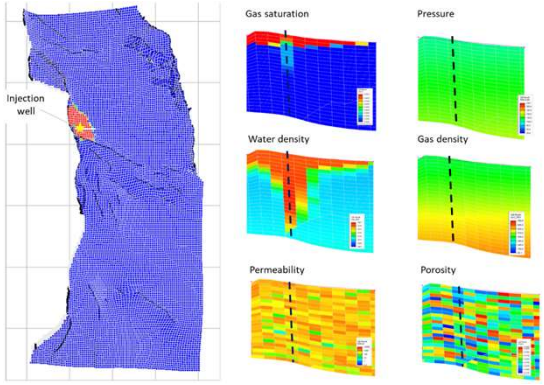
Quantification and data integration

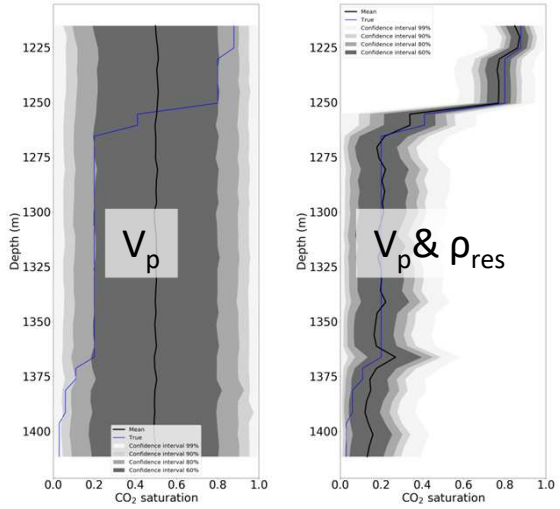
Example: Smeaheia 1D





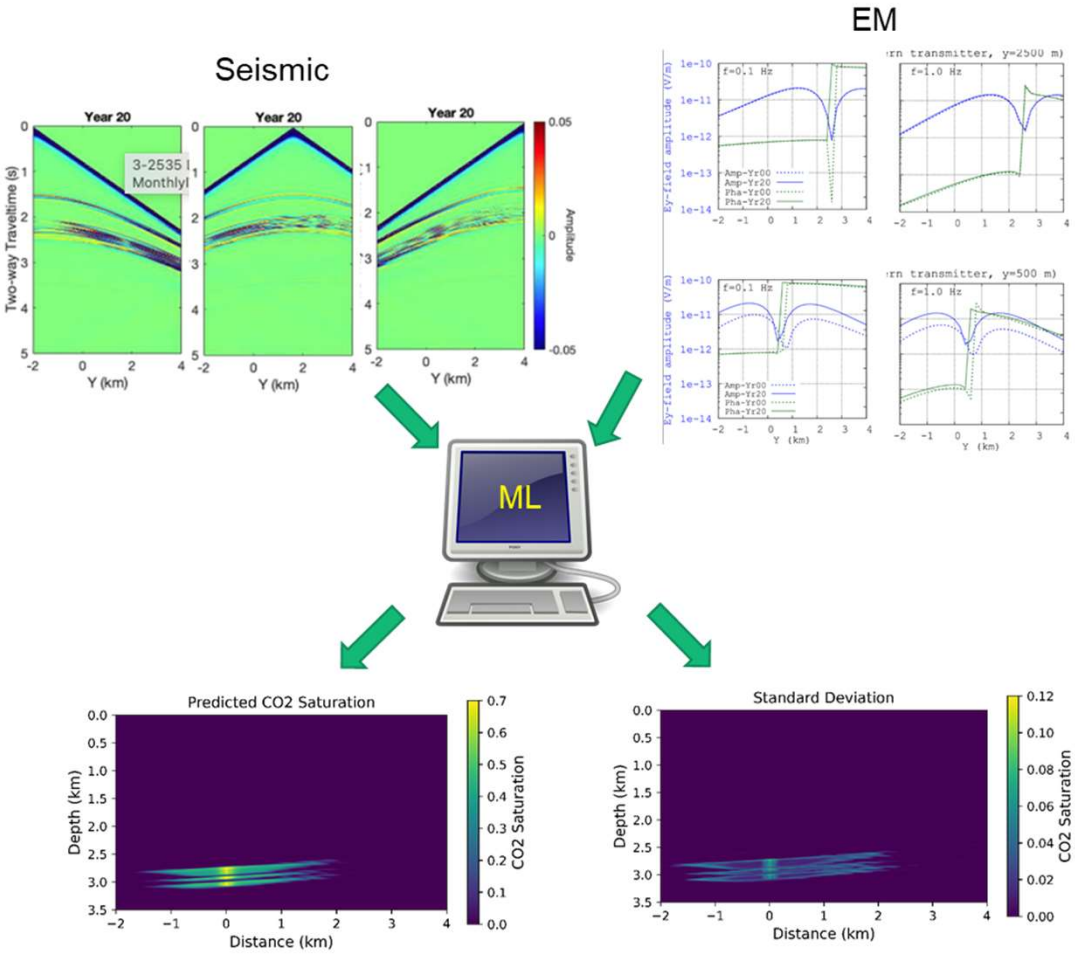






Quantification for conformance assessment

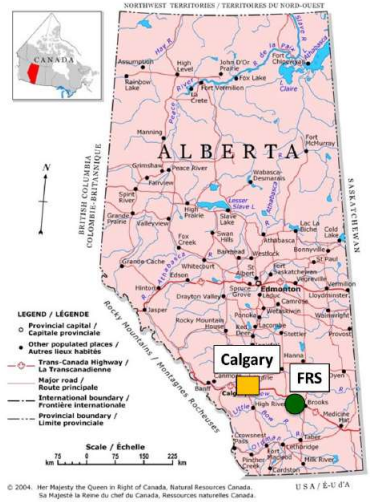
- Test different approaches:
  - Geophysical and RP inversion
  - Direct approaches (ML)
- Extract sufficient information from sparse data
- Multi-method / multi-attribute
- Additional independend observations
  - Surface deformation
  - Microseismic events
- Must be automatized

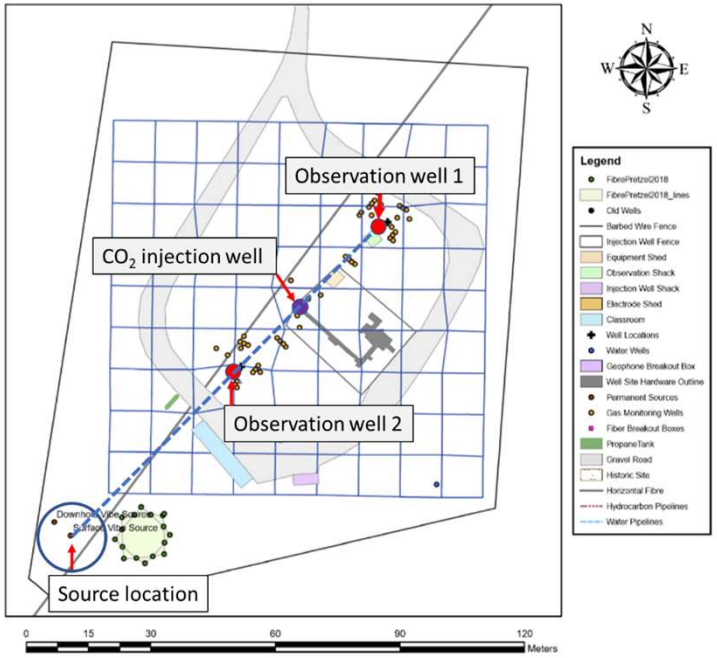


LBNL

Permanent source acquisition tests

- Field testing of sources and deployment
- Conducted at CaMI.FRS site in Canada
- Installation modes (e.g., steel helical piles)
- Different source types
  - Orbital vibrators
  - Vibrators
  - Thumper source
  - HyFold plasma source
- DAS sensing arrays / antennae





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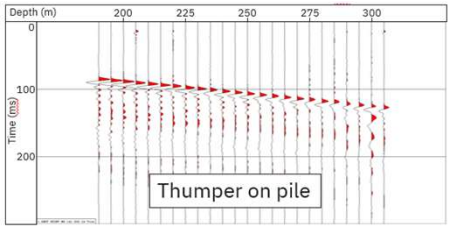
Orbital vibrator

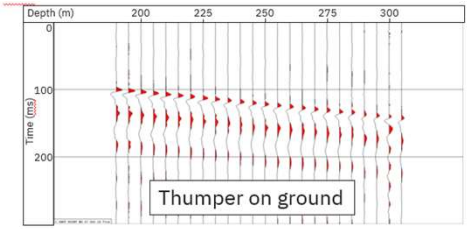
Hyfold bolted to pedestal (seen from above)

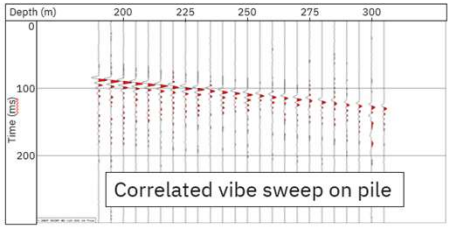
FIG. 2. The USAInc compressed nitrogen accelerated weight-drop source as delivered.

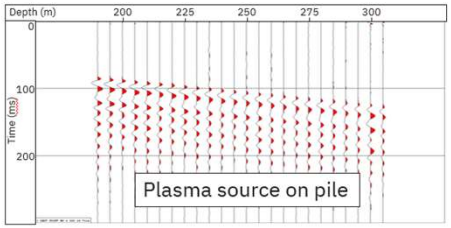
Lawton et al., 2013

Kevin Bertram (CREWES) operating the thumper at CMC's Newell County Facility









Summary

- SPARSE: Establish sparse nodes for low-cost, long-term CO_2 monitoring
- Background monitoring
  - May trigger target oriented surveys where/when necessary
  - May reduce/remove need for costly full 3D monitoring
- Develop nodal system design
  - Integrate geophysical monitoring, conformance assessment, implementation, cost
  - Explore optimum use/exploitation of data
  - Test of components at field labs and using field-scale data.

Acknowledgements

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SINTEF

Teknologi for et bedre samfunn