SPE WORKSHOP

Permanent Reservoir Monitoring Using DAS at the ADM site, Decatur, Illinois

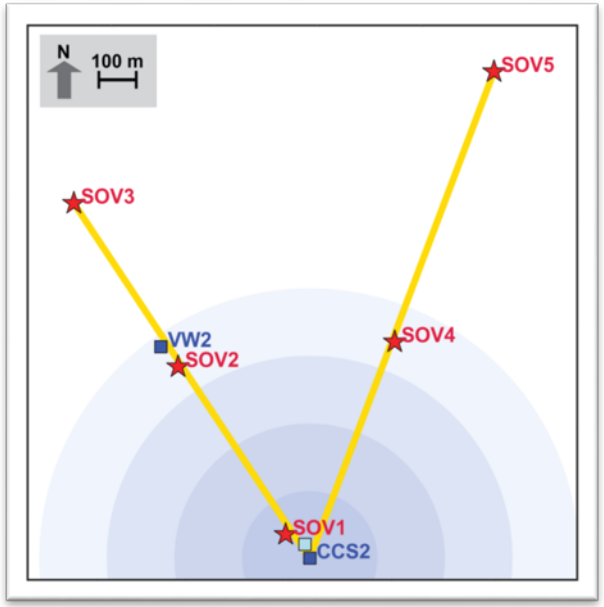
Shan Dou, Jonathan Ajo-Franklin, Todd Wood, Michelle Robertson, and Barry Freifeld

Scott McDonald and Steve Ryan

Joe Greer

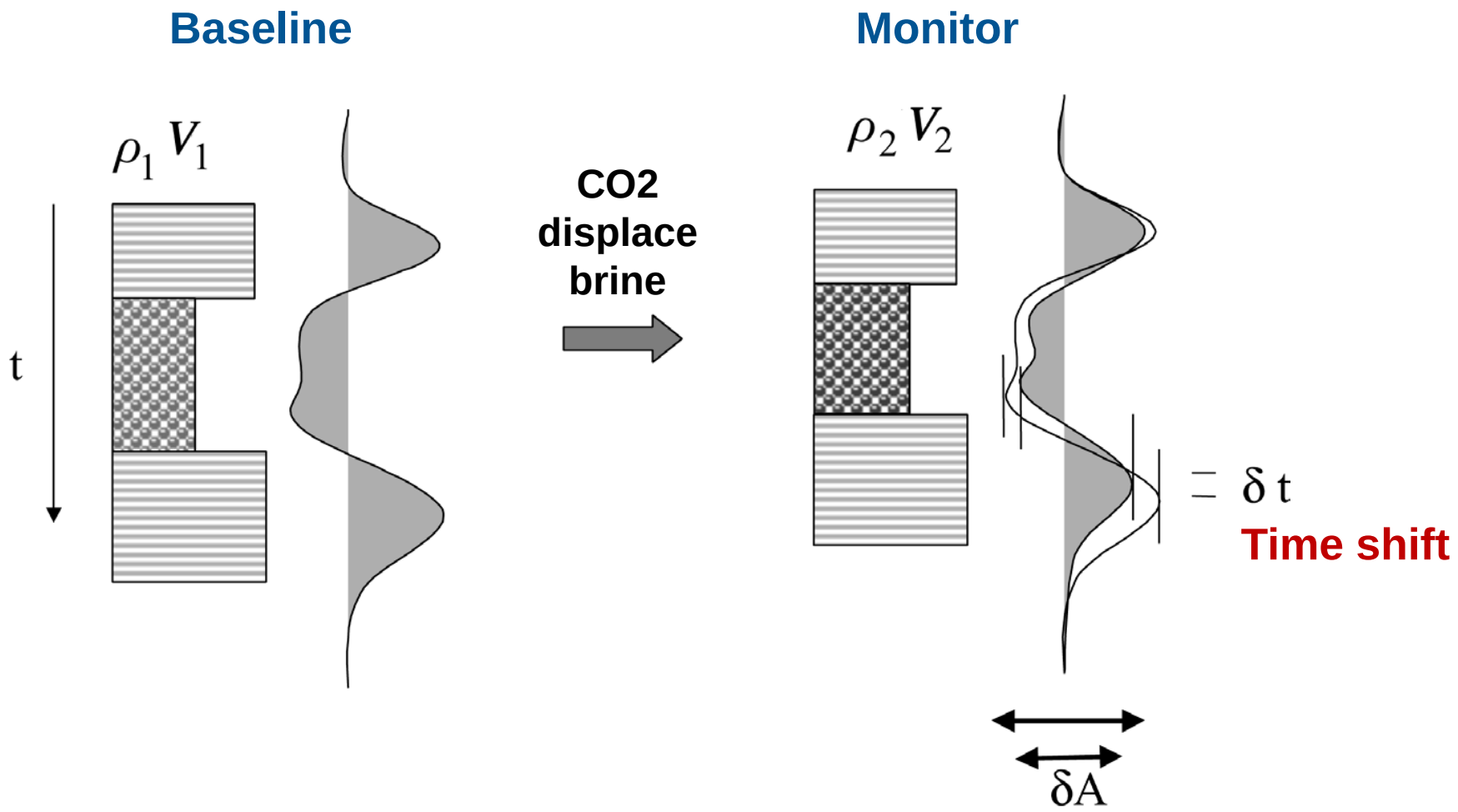
1. Background & motivation
Time-lapse seismic monitoring ≠ 4D seismic

vs.



Time-lapse seismic monitoring in a nutshell

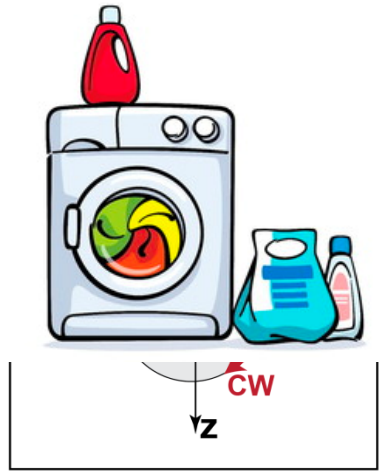
A CO2 sequestration example

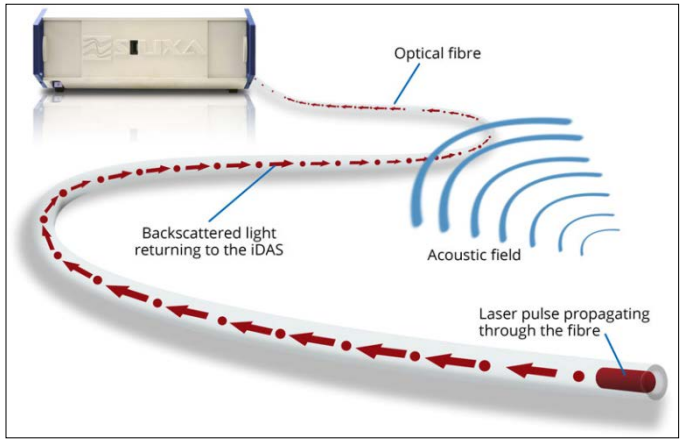


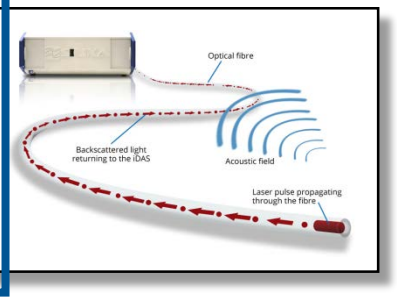
Monitor, respond: when *seeing changes* outweigh high-res imaging

Conventional
campaign-based systems
small T, large N

DAS-SOV permanent monitoring system
large T, moderate N

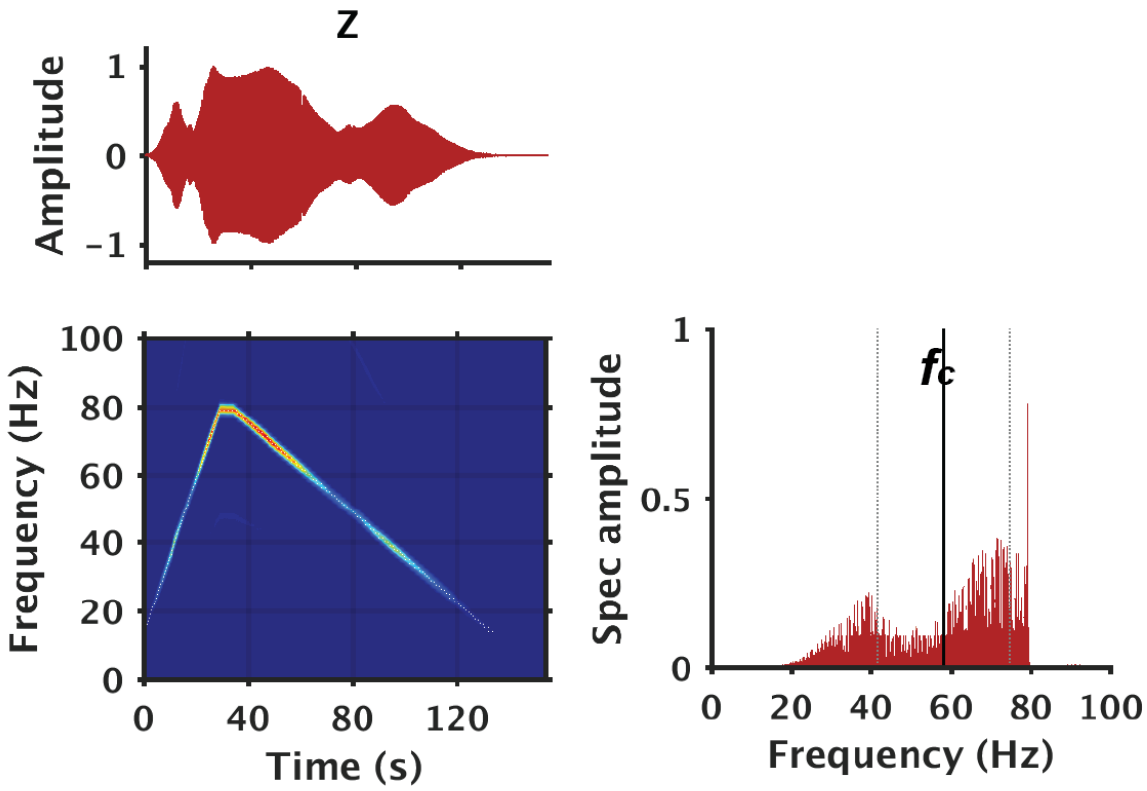






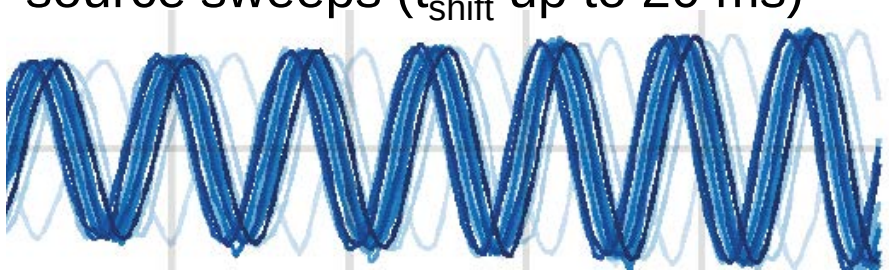
Surface Orbital Vibrator (SOV) for permanent reservoir monitoring

Sweep-based:
controlled release of seismic energy

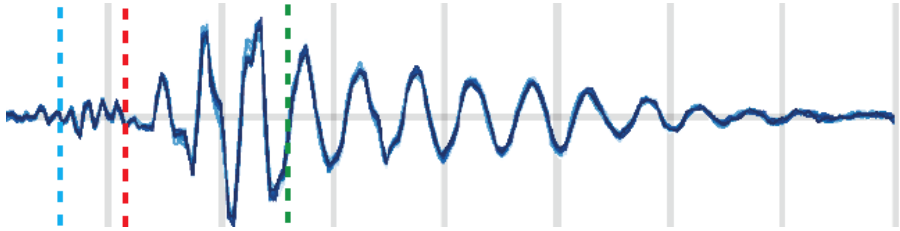


Not phase-controlled:
simpler system

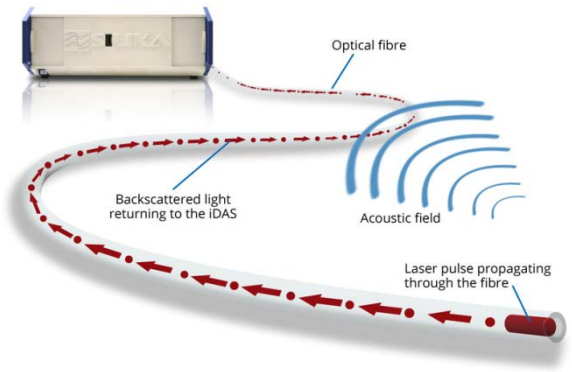
DAS records before deconvolving source sweeps (t_{shift} up to 20 ms)



Same records after deconvolving source sweeps (t_{shift} < 1 ms)



2. Large T, moderate N concept for permanent monitoring
DAS-SOV deployments: an overview



DAS-SOV deployments (since 2015)

2. Fairbanks

Berkeley

3. Decatur

1. Otway

Earlier DAS-SOV deployments: overview & takeaways

1. Otway, Australia:

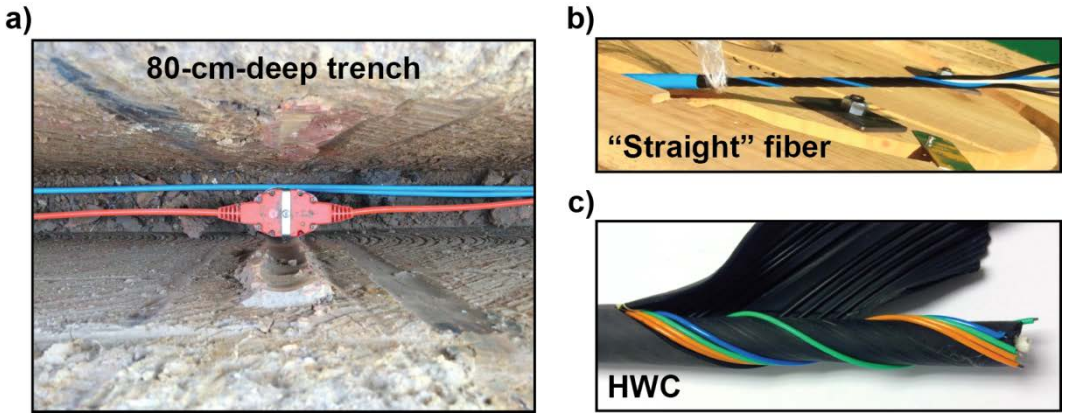
Reservoir monitoring for CO_2 sequestration

Time-lapse survey configuration (~1100 m × 1100 m)

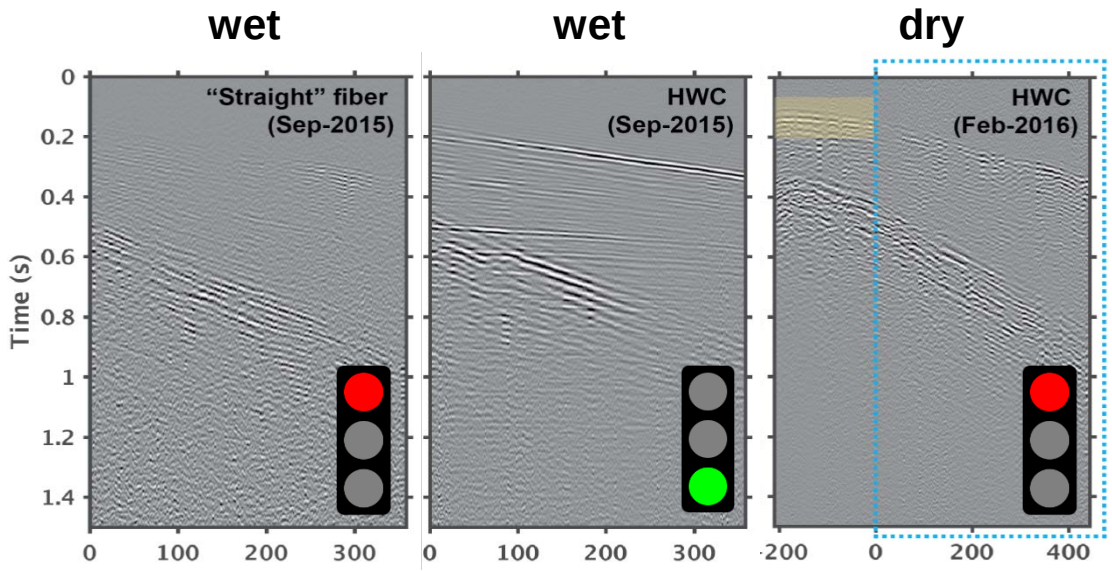
- Sources: Two 10-ton force SOVs, f_{max} = 80 Hz
- Receivers:
  - Buried 5 Hz vertical geophones (depth = 4 m; Δx = 15 m)
  - Trenched DAS (depth = 0.8 m; Δx = 0.5 m)
    - "Straight" fiber: wrapping angle = 11°
    - Helically wounded cable (HWC): wrapping angle = 30°

Key takeaways

- Geophone data show good SOV repeatability:
  NRMS < 21%, Δt < 0.2 ms (Dou et al., *SEG 2017*)
- Signal quality of HWC strongly affected by moisture variations of the unsaturated ground



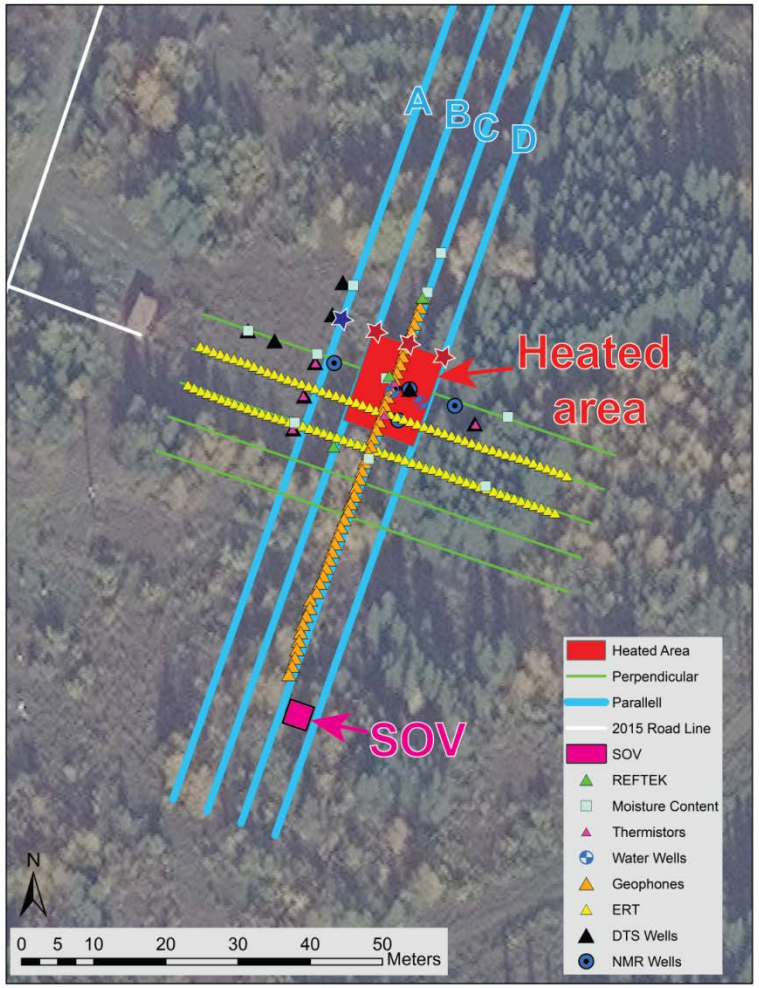
(Freifeld et al., *EAGE 2016*; Dou et al., *SEG 2016*)



Earlier DAS-SOV deployments: overview & takeaways

2. Fairbanks, AK:

Near-surface monitoring of permafrost thaw



(Ajo-Franklin et al., *SEG 2017*)

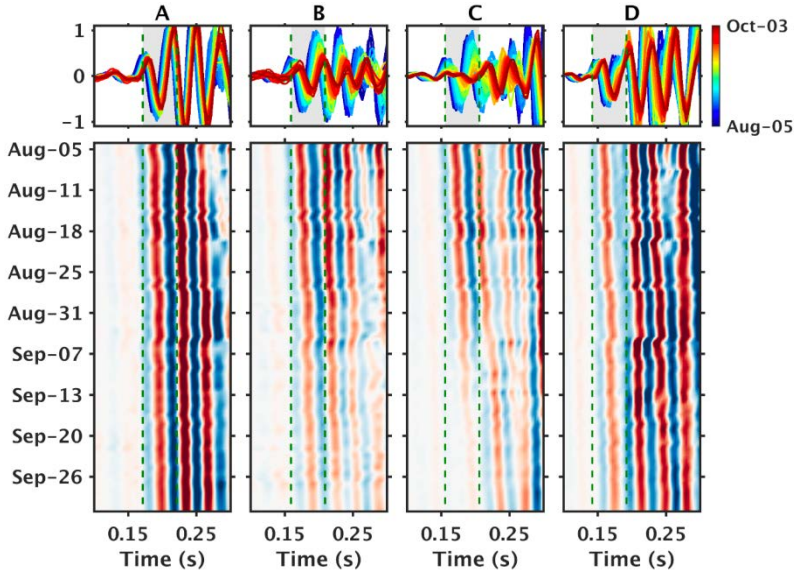
Time-lapse survey configuration (~180 m × 60 m)

- Sources: One 2-ton force SOV, f_{max} = 90 Hz
- Receivers:
  - Three broadband seismometers
  - Trenched DAS (depth = 0.2 m; Δx = 1.0 m)

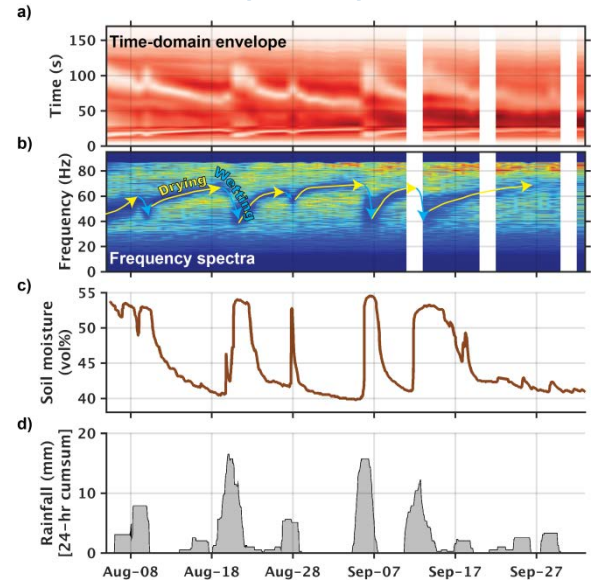
Key takeaways

- Source sweeps recorded by pilot geophone strongly affected by precipitation events
- DAS-recorded body waves show time-lapse changes characteristics of permafrost thaw: reduced velocity and amplitudes

DAS-recorded S waves



Source sweeps respond to rainfall



(Dou et al., *in preparation*)

Earlier DAS-SOV deployments: overview & takeaways

2. Fairbanks

Berkeley

3. Decatur

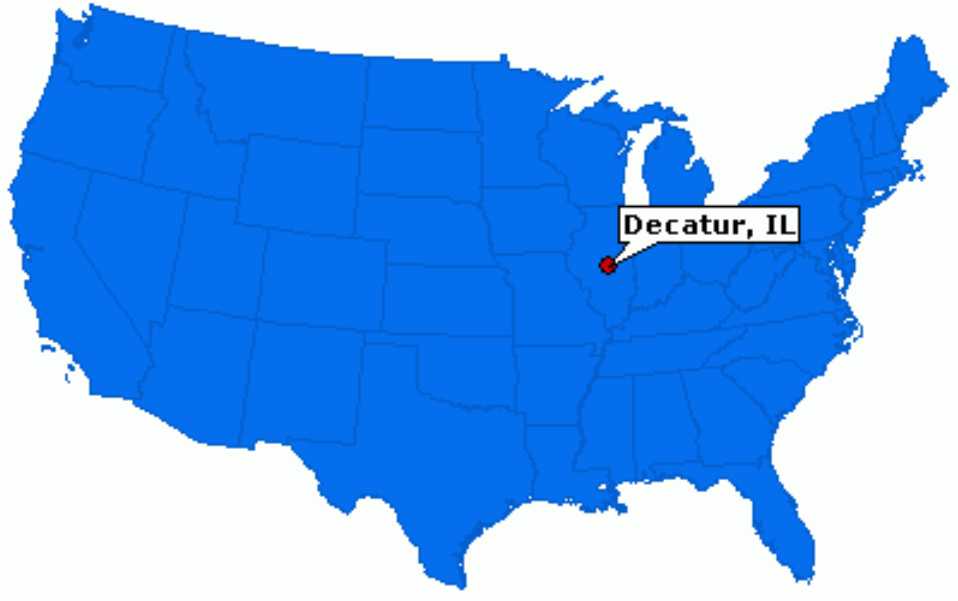
1. Otway

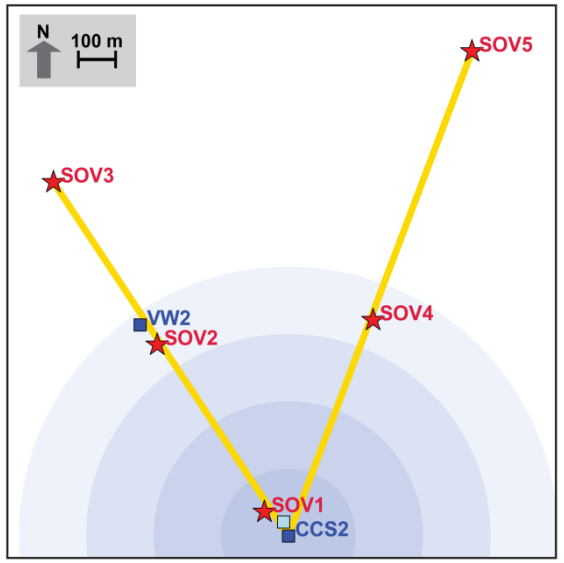
Deeper installations of pilot geophones + soil moisture measurements are needed/worth trying

Install HWC cables in saturated, below-water-table soils may improve signal quality

3. The ADM project

The ADM deployment at Decatur, Illinois





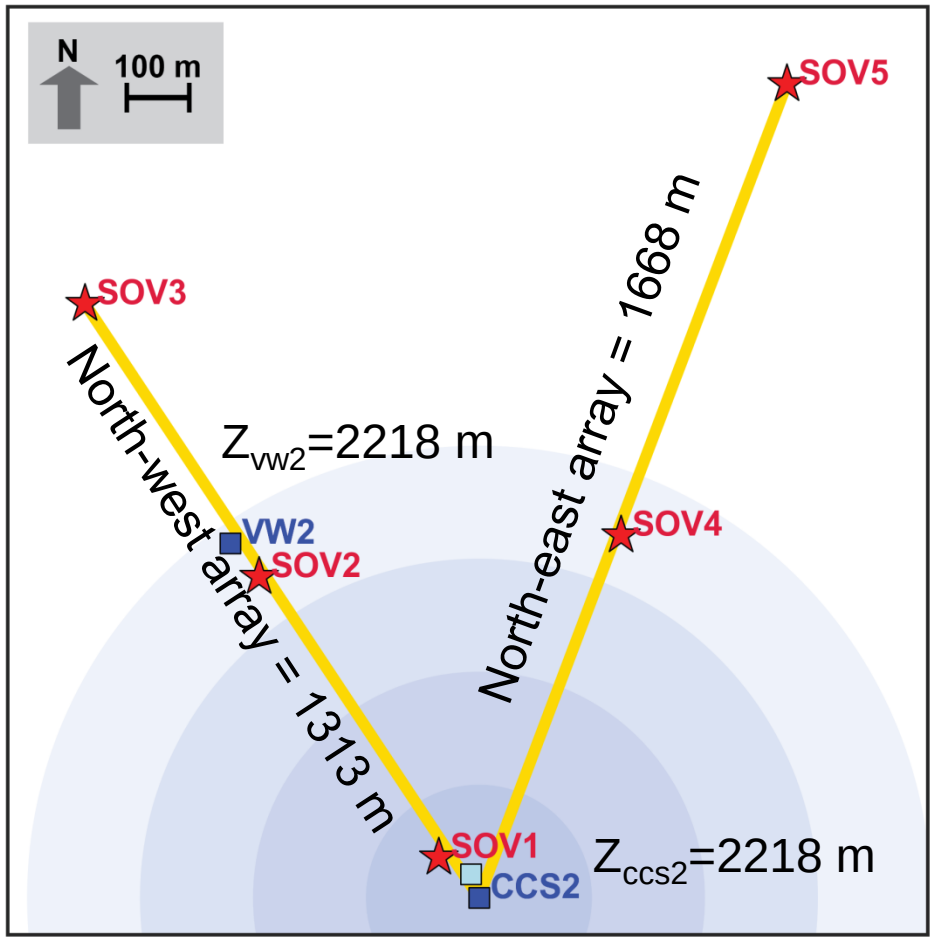
DAS-SOV monitoring of GCS at the ADM site (>1 million tons per year)

GCS = geological carbon sequestration

Injection well CCS2

SOV-DAS monitoring system layout

SOVs: 10-ton force; Surface DAS: HWC at **6 m depth**



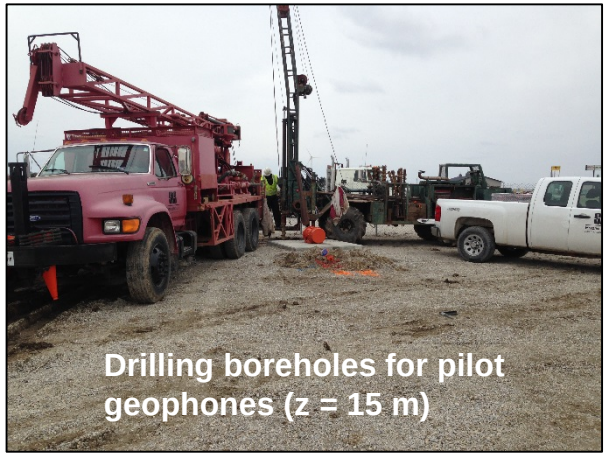
Injection

SOV installations at the ADM site

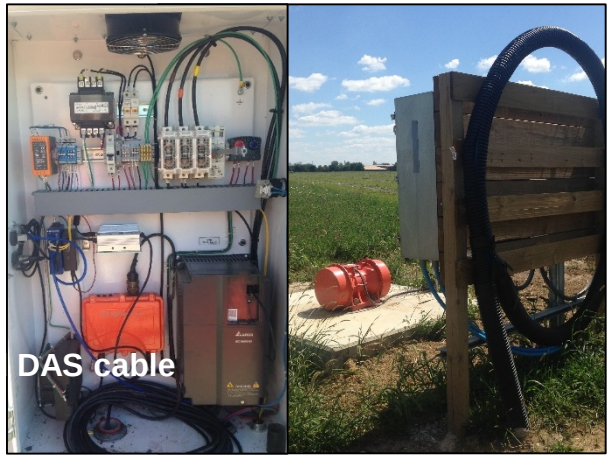

Foundation excavation


Structural SOV Anchor Assembly


Mounting SOV


Drilling boreholes for pilot geophones (z = 15 m)


SOV Control and Splice Panels


DAS cable

“Trenchless” DAS install with Horizontal Directional Drilling (HDD)

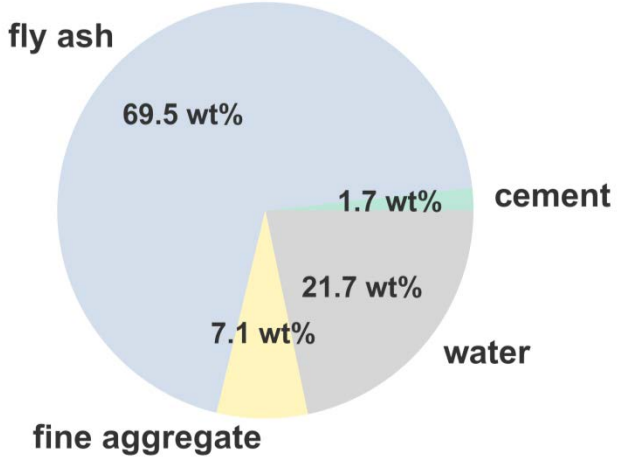
4. HDD at the ADM site

HDD unit at the entrance pit

Locating the pilot bore

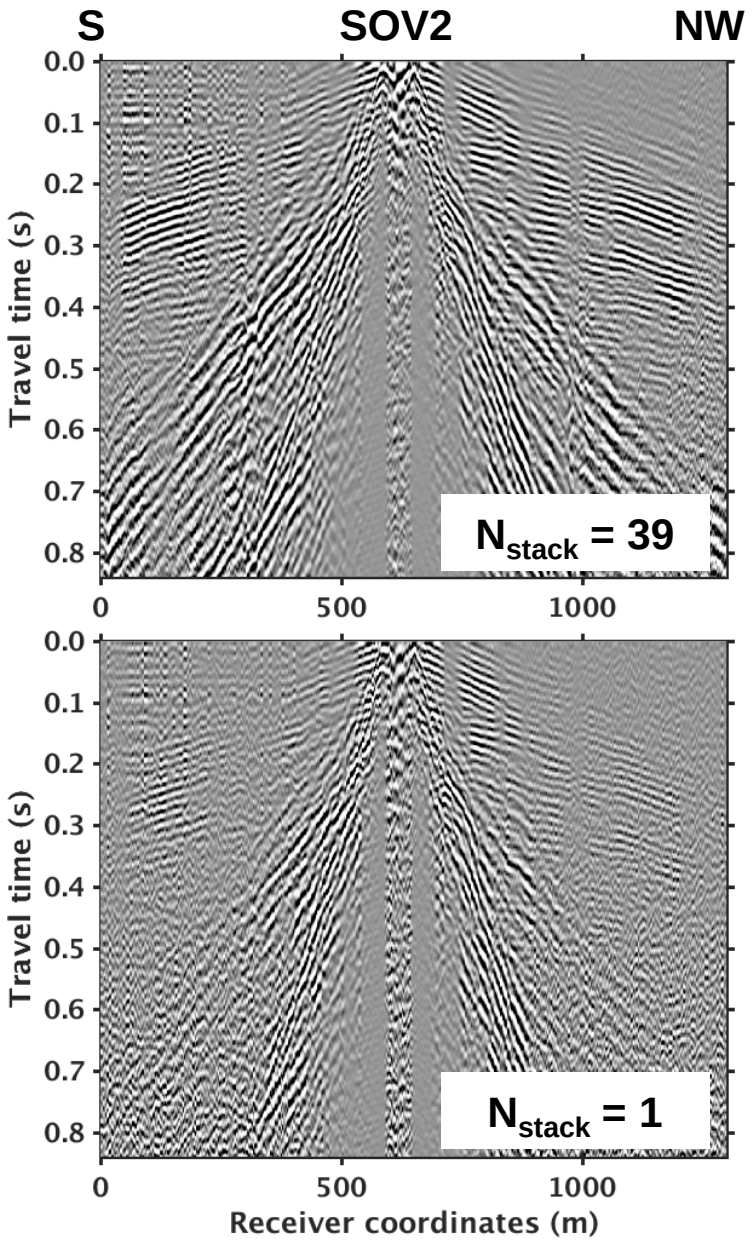
Pull fiber-optic cable and grout conduit

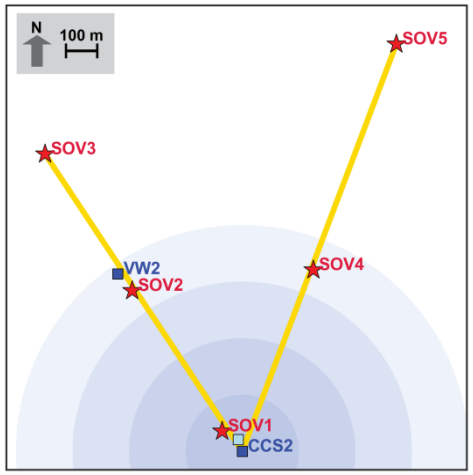
Grouting to improve DAS-ground coupling



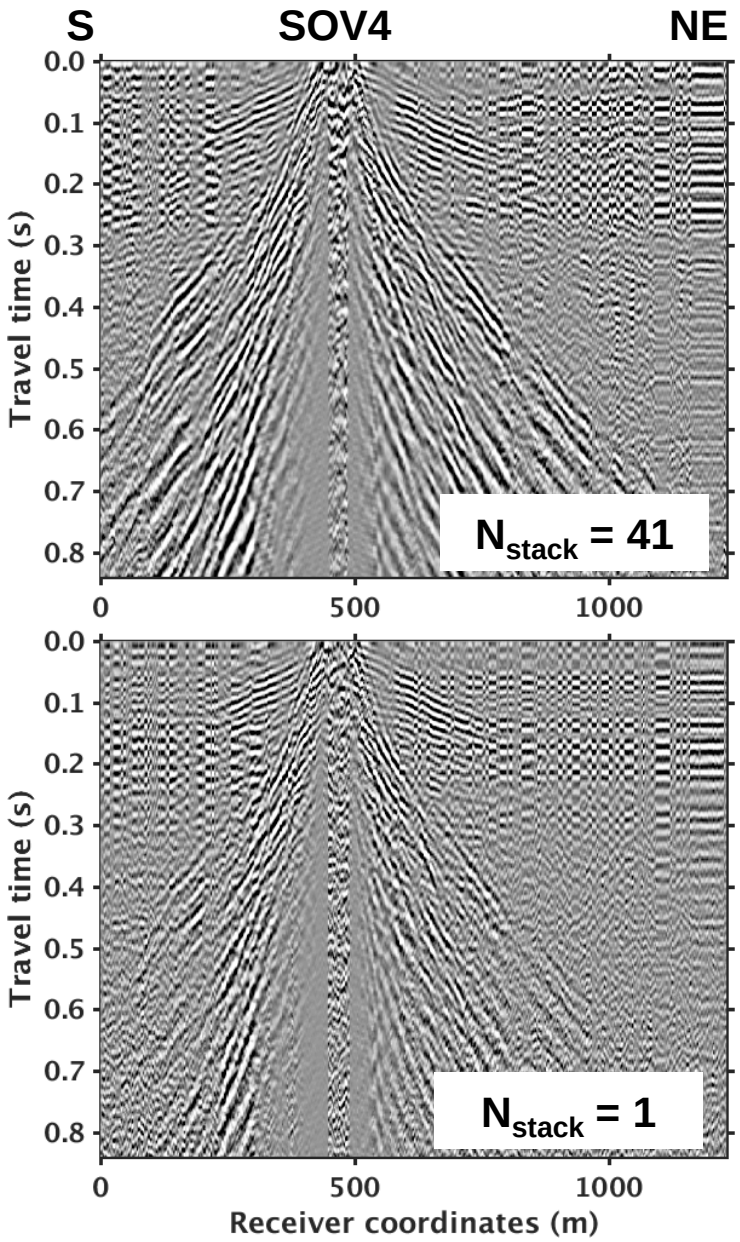
Grout recipe for optimal impedance match with the surrounding earth

Data examples: surface HWC DAS (preliminary)

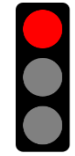




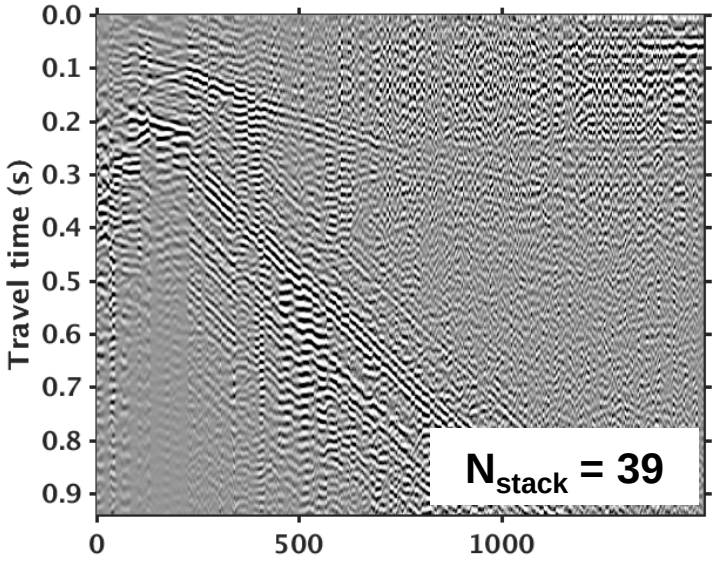
- Visible PP reflections
- Improved deconvolution procedure could further improve signal quality

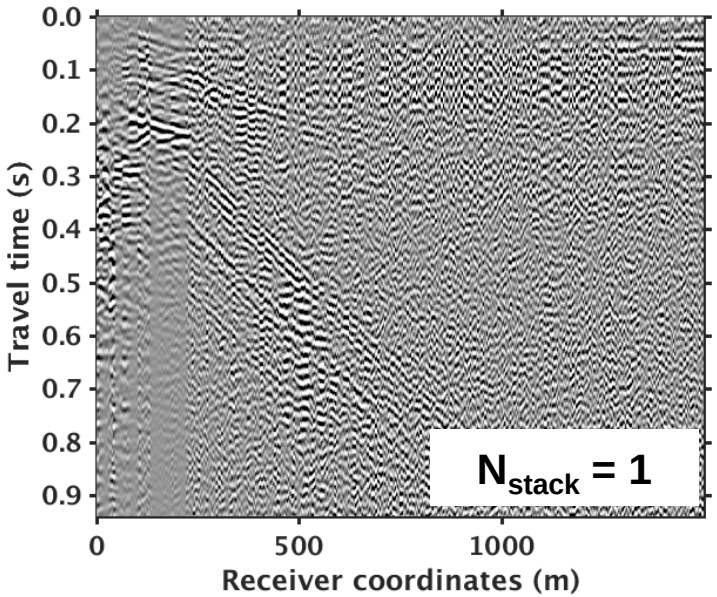


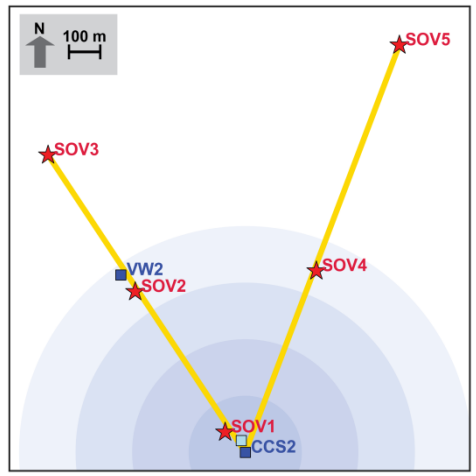
Data examples: downhole straight DAS (preliminary)



SOV2-VW2

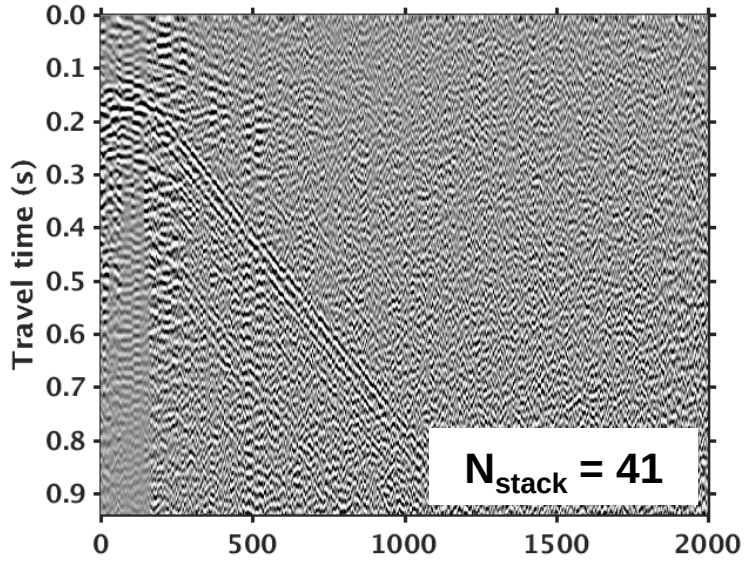


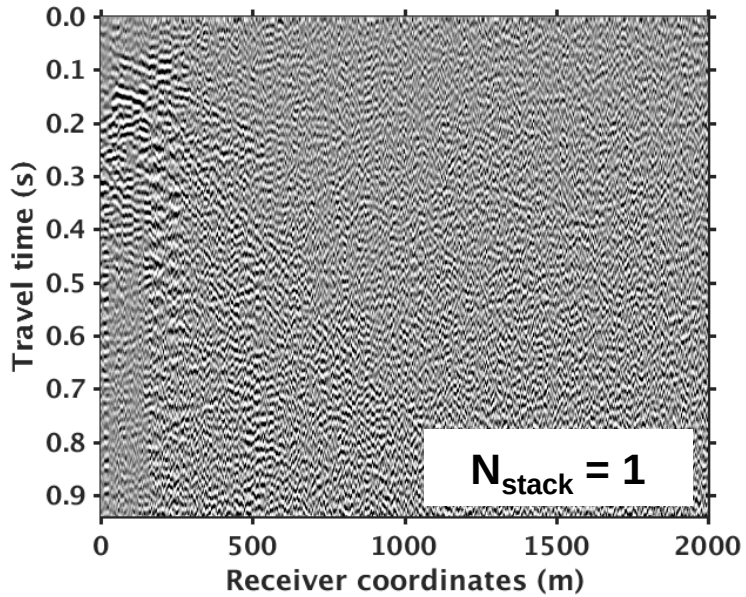




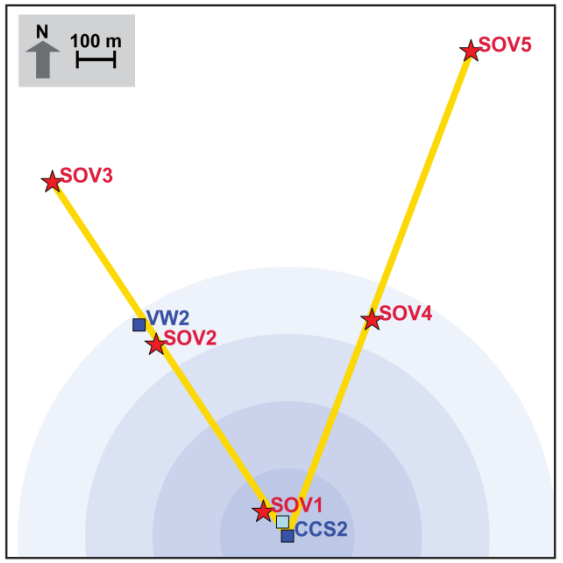
- Low signal content due to poor DAS-ground coupling
- Suggests “blown-in” fiber not adequate for DAS

SOV1-CCS2





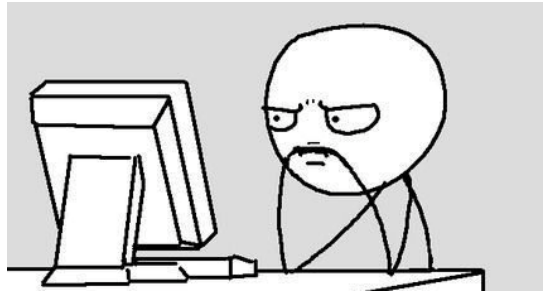
4. Challenges and the road ahead
The data engineering challenges



When 2TB/day data load encounters network firewall

100 MB/s

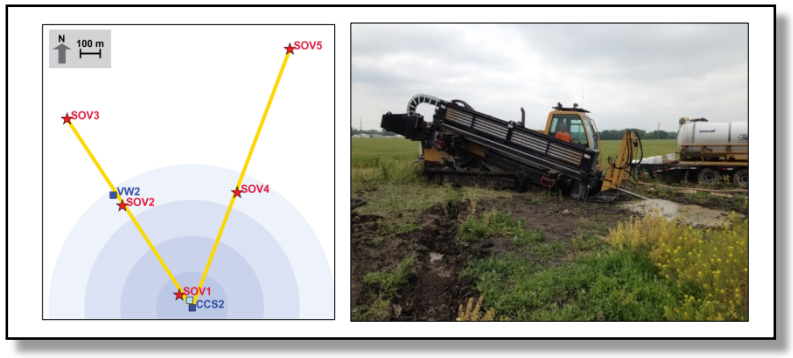
What we need:
-Overcome bottlenecks
-Smarter data compression and management schemes for big seismic data



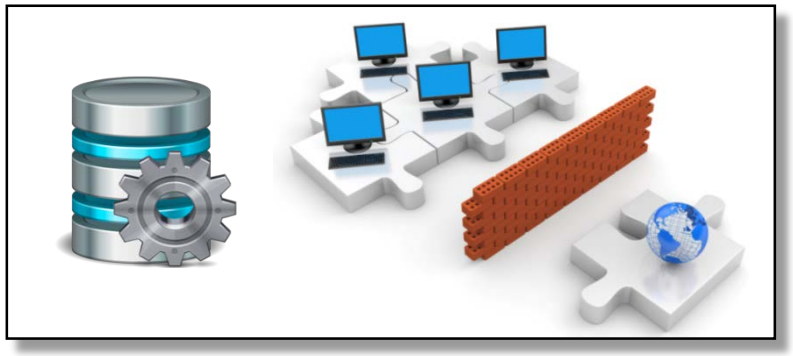
2 MB/s

Conclusions

DAS-SOV system is a cost-effective option for permanent reservoir monitoring (large T, moderate N)



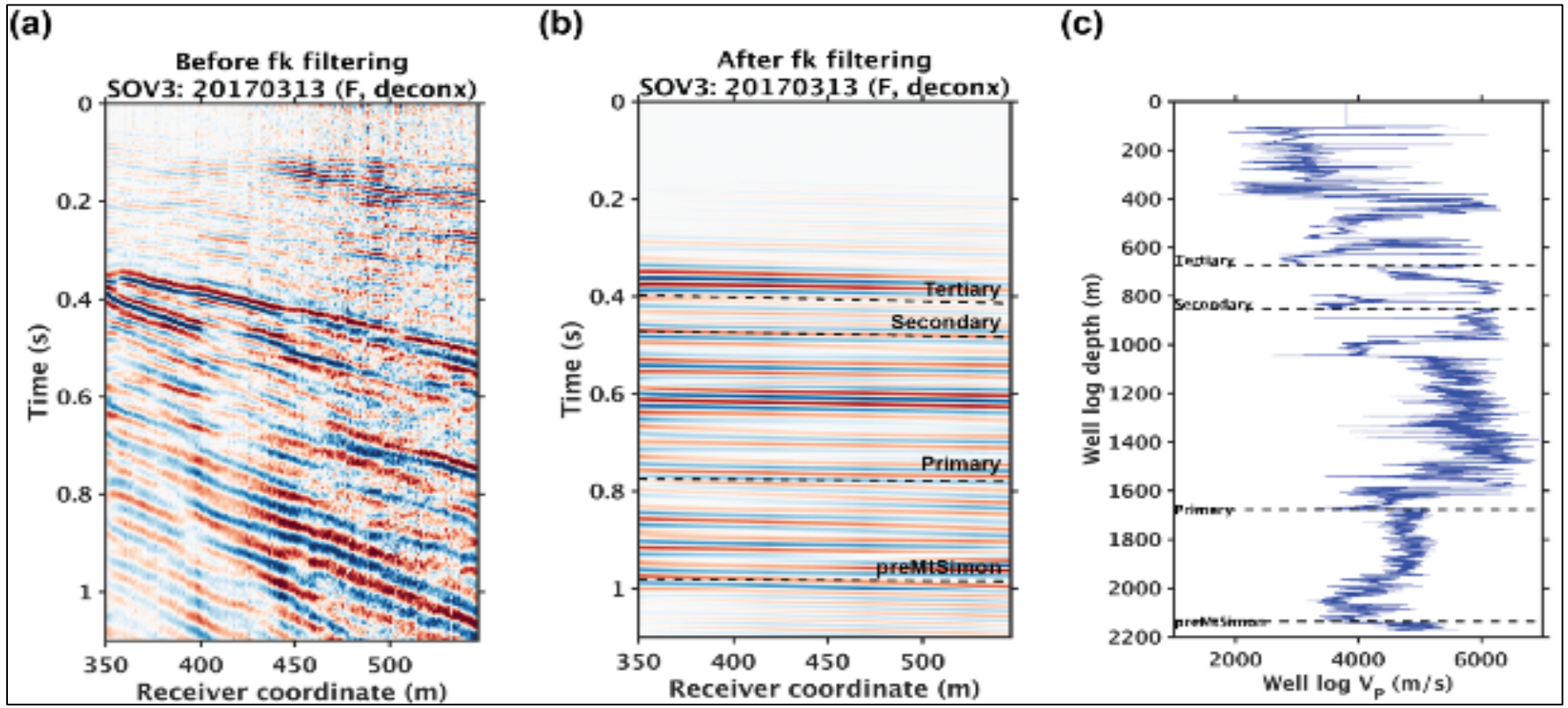
Trenchless installations of surface DAS arrays at the ADM site with horizontal directional drilling (HDD): lessons learned and data examples



Data engineering challenges of the ADM project call for overcoming firewall bottlenecks and smarter data shuffling strategies

Thank you

Questions?


(a)
Before fk filtering
SOV3: 20170313 (F, deconx)
Time (s)
Receiver coordinate (m)
(b)
After fk filtering
SOV3: 20170313 (F, deconx)
Tertiary
Secondary
Primary
preMtSimon
Time (s)
Receiver coordinate (m)
(c)
Well log depth (m)
Well log V_P (m/s)