TOWARDS INTEGRATED SEISMIC MVA FOR NEAR-SHORE GCS: DAS + PERSISTENT SOURCES

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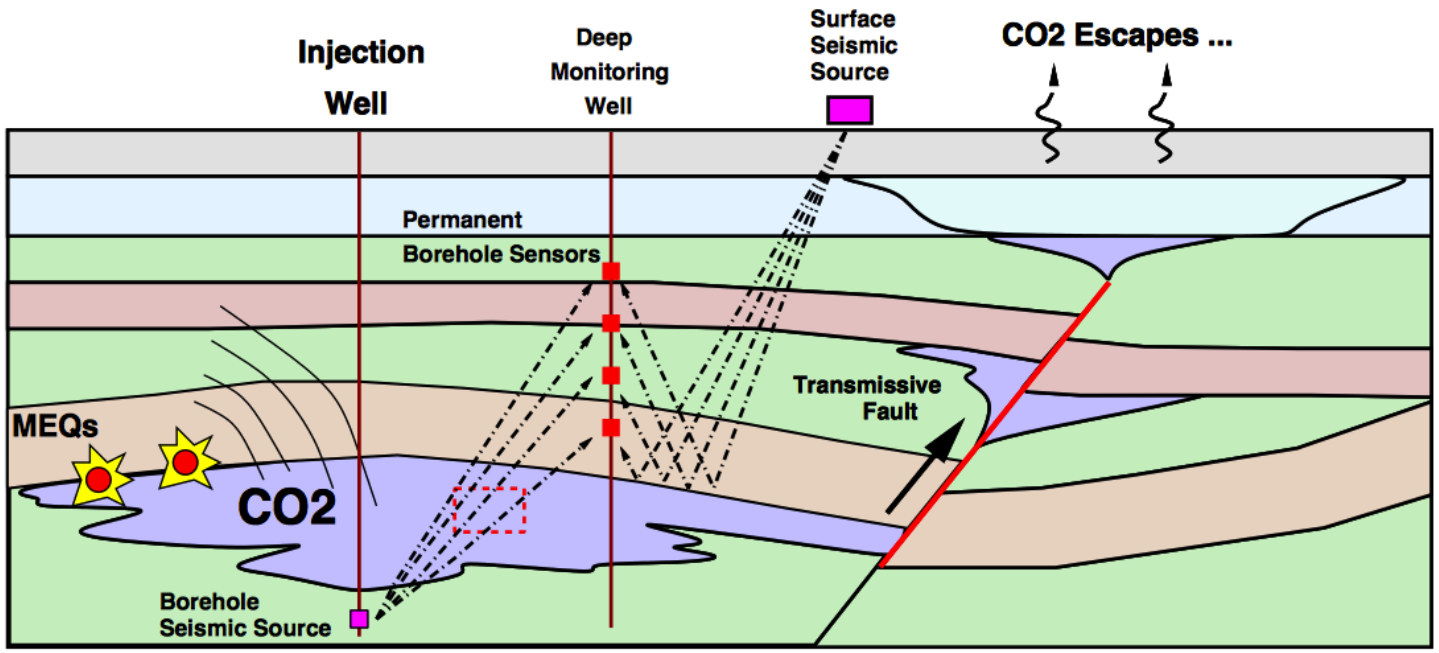
Partnership for carbon capture & offshore geologic storage GoMCarb

GCCC Gulf Coast Carbon Center

Bureau of Economic Geology

NETL National Energy Technology Laboratory

MVA Challenges in Shallow Offshore Environments



[A] Plume Extent

[B] Internal Saturation

Total Plume Mass?

[C] Leak Conduit

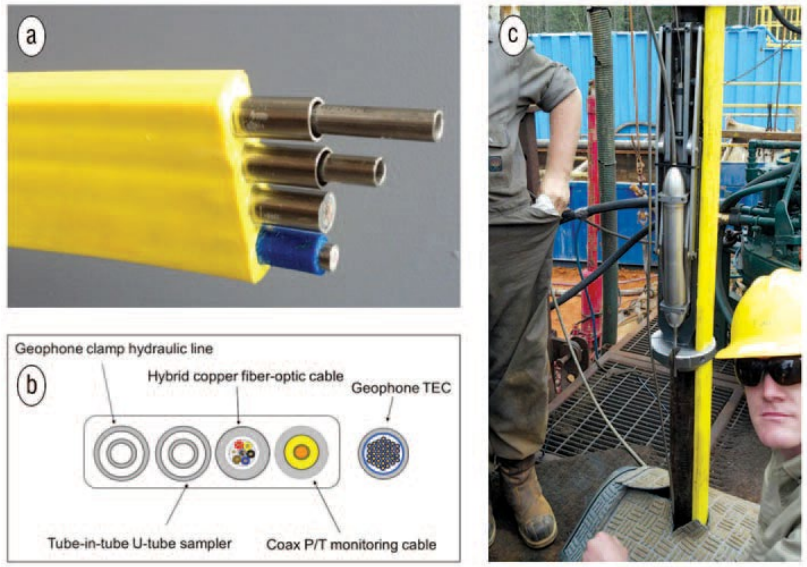
[D] Region of Escaped CO2

Challenges for GomCARB include ....

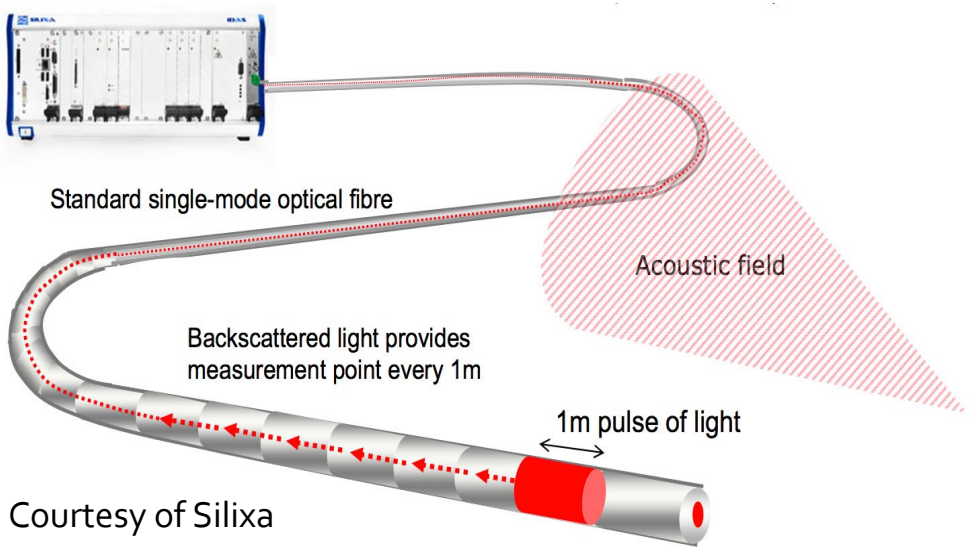
- Need to consider deep CO_2 movement (reservoir), intermediate/shallow leakage, seafloor expression, and water column (+ pipeline?).
- All in the context of a petroleum province with a dynamic seafloor, abundant natural gas seeps, storm impacts.
- Expensive wells (& completion ops) suggests less dependence on borehole monitoring beyond injector.
- Seafloor environment hostile to traditional long-term sensing (as well as costly), particularly for high sensor densities. Consider maintenance.
- Need to monitor seafloor and deep subsurface without direct access besides shallow draft vessel and ROV.
- One plus : Marine 4D simpler/high S/N than land.

Two New(ish) Technologies for MVA : DAS & Persistent Seismic Sources

- **Distributed Acoustic Sensing [DAS]** is a rapidly advancing approach for measuring the seismic wavefield using commercial fibers (SM, telecom)
- Easy to deploy in wells, behind casing, seafloor, 1000s to 100,000s of channels available (big data) over 10+ km
- *Very low cost per "sensor"* : $/ft for cable
- *Rugged* : handles high/low T, high pressures, aquatic environments.
- Once fibers are there, other sensing modalities simple (DTS, DSS etc).
- ***LBNL Strengths*** : unique deployment packages, cable modifications, system integration, application domains, processing & inversion strategies.



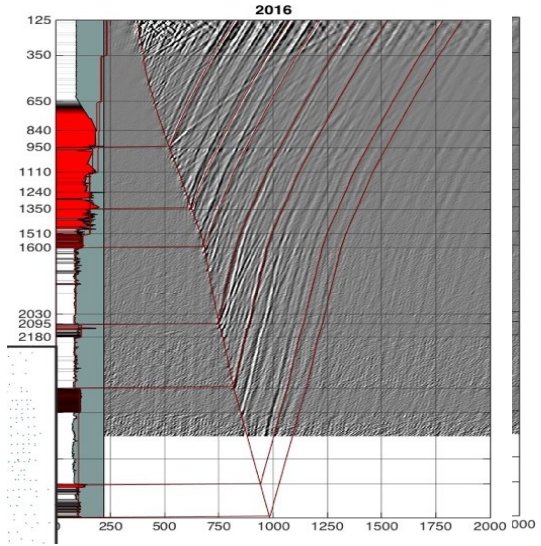
Daley et. al. 2016 (Geop Prosp.), Miller et al. 16, Daley et.al. 2013, (TLE)

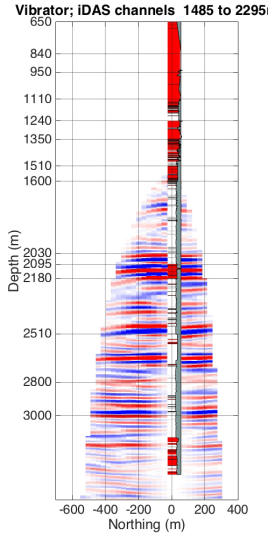


Courtesy of Silixa

For GCS:
Past LBNL deployments at Citronelle, Aquistore, Otway, CaMI, ADM for VSP (ADM only surface test, rest are borehole)

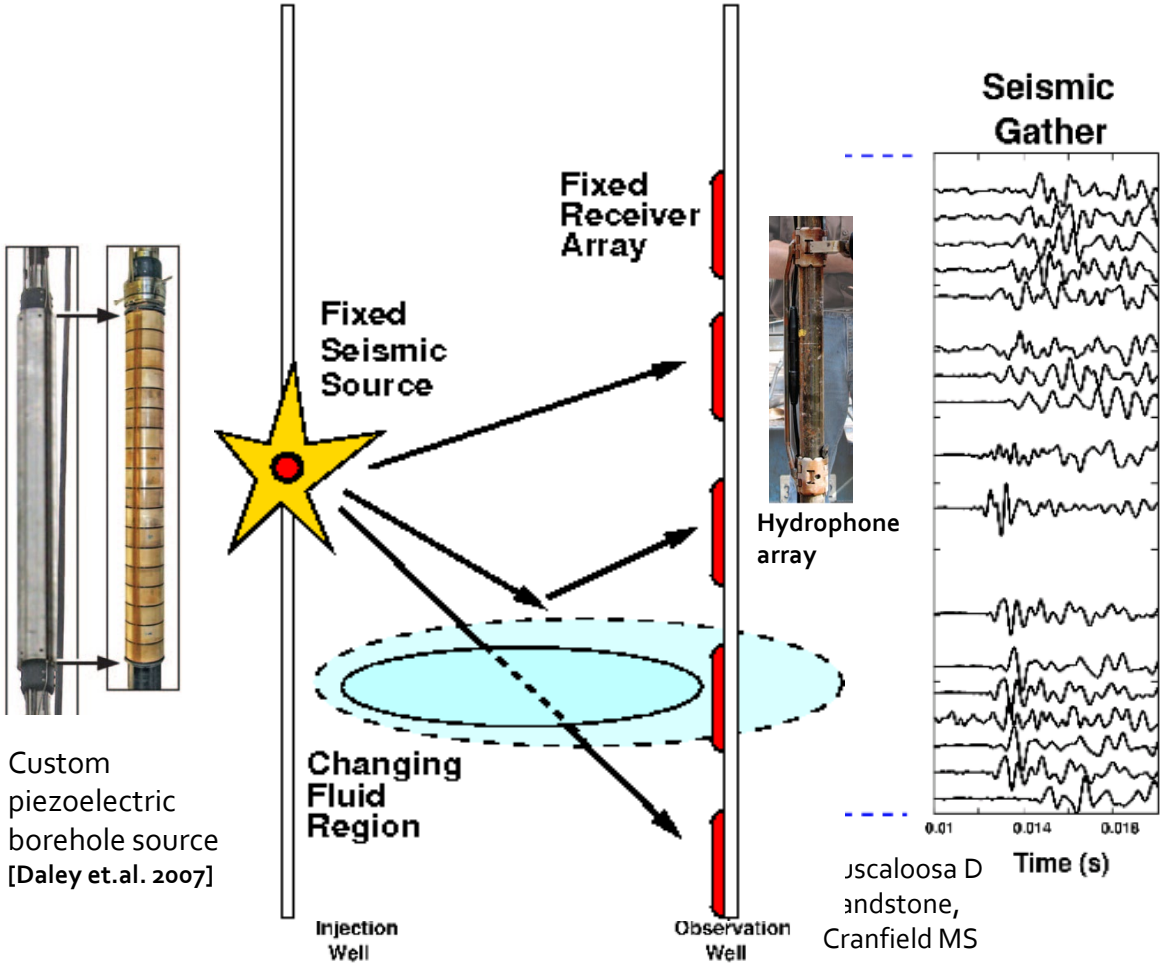
GomCARB:
- First time we are considering offshore
- First exploration of seabed
- First exploration of shallow/deep imaging combined





Two New(ish) Technologies for MVA : DAS & Persistent Seismic Sources

- Large permanent seismic arrays (DAS) require sources (!).
- Need matching high-temporal resolution measurements in the field.
- For MVA, need sources to illuminate both deep (reservoir), near seabed, and water column perturbations.



Custom piezoelectric borehole source **[Daley et.al. 2007]**

uscaloosa D andstone, Cranfield MS

CASSM :
Continuous Active Source Seismic Monitoring

Fixed repeatable source & receiver array. LBNL has worked on piezoelectric and rotary source designs

- Temporal Resolution (< 5 min)
- Precise repeatability (~10 ns)
- Stacking -> Excellent S/N
- Real-time Acquisition
- Borehole & surface sources.
- Deployment to 10,500 ft & 120 C
- Largest deployment 22 S x 72 R
- Moving towards real-time seismic tomography

EESA developed and fielded at 12+ sites to date.
GCS tests at Frio 2, Cranfield Phase 3 (borehole), Otway, ADM (surface) [Daley et al. 2007, Daley et al. 2011, Marchesini et al. 2017, Zhu et al. 2018, Zhu et al. 2019]

GomCARB :

- Opportunity to consider **water column** broadband sources
- Mount near platform for combined surface (shallow/deep) and VSP monitoring?
- Provide time points between 4Ds

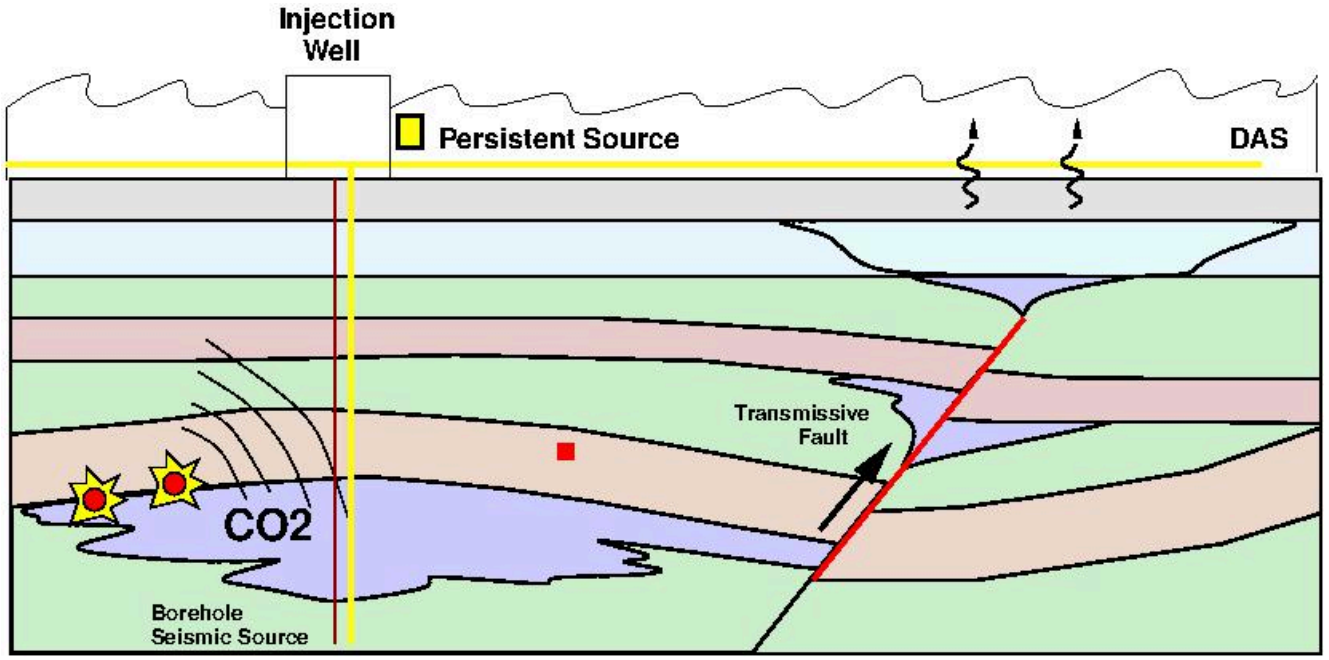
Concept :
Integrating DAS + Marine Persistent Sources (CASSM) Near-Offshore MVA

- **Use DAS on the seafloor (and wellbore) as linear seismic array** for imaging
  - Near-surface anomalies (CO_2 leakage), Deep subsurface (CO_2 migration) & microseismic
  - Noise from relevant processes (bubble emission etc).
  - Replaces OBS or seafloor hydrophone deployments.
  - Better time resolution than repeat streamer surveys, much cheaper than LoFS using cabled OBS. Also permanent receivers for 4D

  [note : technology also has a potential role for pipeline monitoring in future tests]

- **Use fixed seismic source in the water column for high repeatability imaging** (Marine CASSM
  - highly repeatable timelapse monitoring of the near-seabed sediment, water column, and deep subsurface.
  - Considering novel swept source with resonance for combined reflection/transmission/VSP.

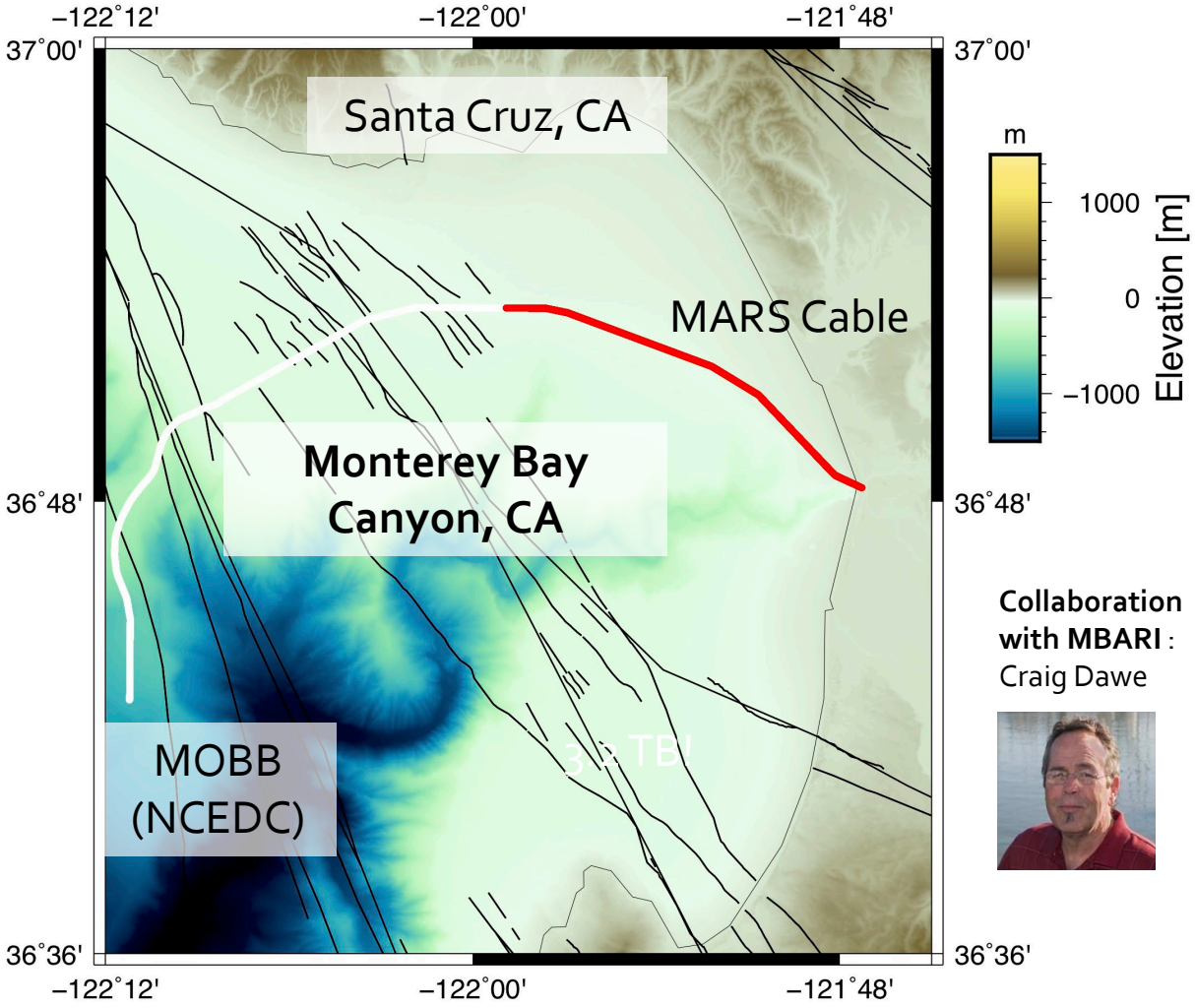
- **Combined system for seismic MVA with high (minute) time resolution in marine environment**
  - Unique aspect is combination of shallow (leakage) and deep (reservoir) targets.
  - Challenges are understanding deployment challenges for system elements



LBNL MVA Tasks (5 years)

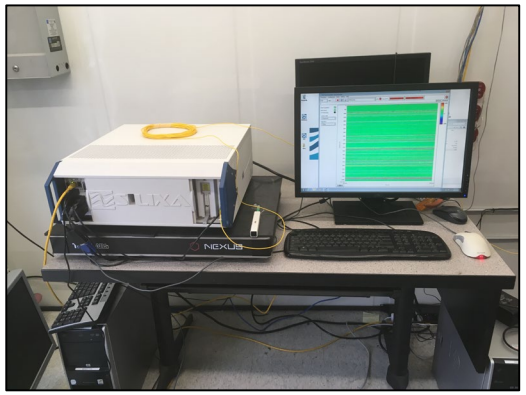
- ***Task 1 : Design and Modeling Stage***
  Design and modeling of the proposed source & integrated source/DAS system in a marine environment for CO_2 leakage tracking.
- ***Task 2 : Source Construction and Laboratory Tank Testing***
  Construction of prototype source/tank tests. Evaluate for (a) water column, (b) near-seafloor, and (c) deep subsurface imaging targets.
- ***Task 3 : Analysis of Seafloor DAS Dataset***
  Analysis of a DAS dataset acquired on an existing seafloor cable to examine noise characteristics and response in a near-shore environment. (datasets of opportunity!)
- ***Task 4 : Broad MVA Support***
  Collaborate with TX BEG more broadly to develop fit-for-purpose monitoring suited for the near offshore environment.
- ***Task 5 : Design and Execution of a Shallow Water Field Test***
  Near-offshore field test. Similar water depths to pilot. Possible short N_2 bubble release along a DAS profile illuminated by the persistent source, designed to test monitoring (a) near-seafloor subsurface velocity perturbations, (b) acoustic noise from release (c) changes in acoustic transmission in the water column.
- ***Task 6 : Evaluation of Fiber Optic Cables in the GoM Available for DAS***
  Our last task is evaluation of existing fiber optic cables in the GoM which might be leveraged for DAS recording as part of a near-shore GCS monitoring network.

DAS on Offshore Seabottom Cables? MBARI Evaluation Dataset (Task 3)

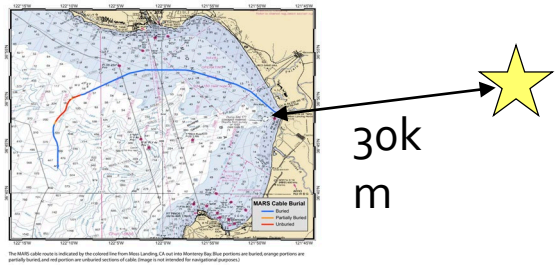


Collaboration with MBARI : Craig Dawe

- A dataset of opportunity – 1st offshore cable DAS dataset (that I know of) processed for seismic.
- Umbilical cable to MOBB – offshore tethered observatory
- Explore passive signals recorded with ~20km MARS cable with Silixa iDAS at Moss Landing (MBARI headquarters)

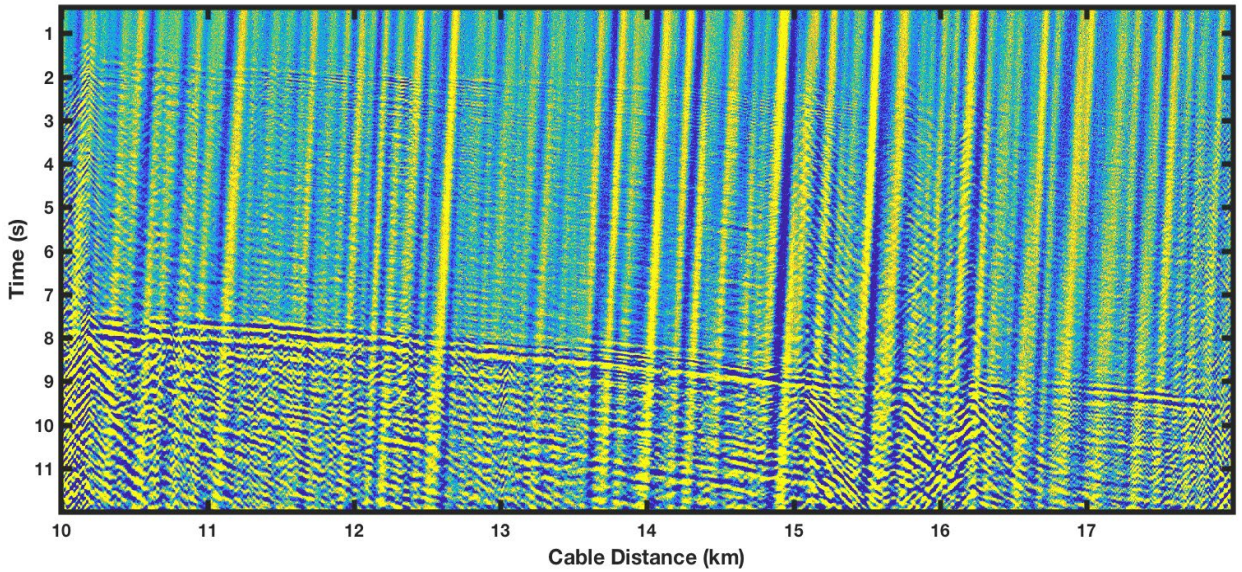


Detecting Seismicity Using Marine Seabed Fiber & DAS?

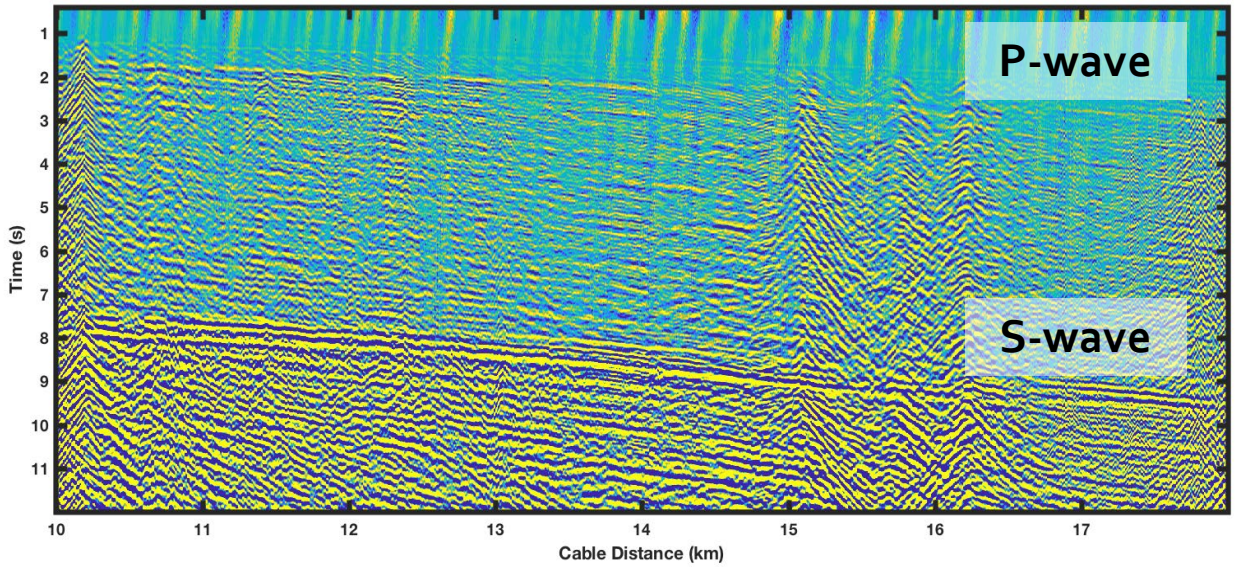


30k m

- Several on-shore EQs detected during short deployment. M3.4 in Gilroy (~30 km). Also picked up several smaller (M2) events, same hypocenter.
- Signal cleaner than on-shore recordings for local events.
- Wave motion (primary/secondary microseisms) overprint – easily removed.
- Scattering features which may correspond to offshore fault systems?
- Will be a powerful tool for probing near- offshore fault systems & potential **induced seismicity**.

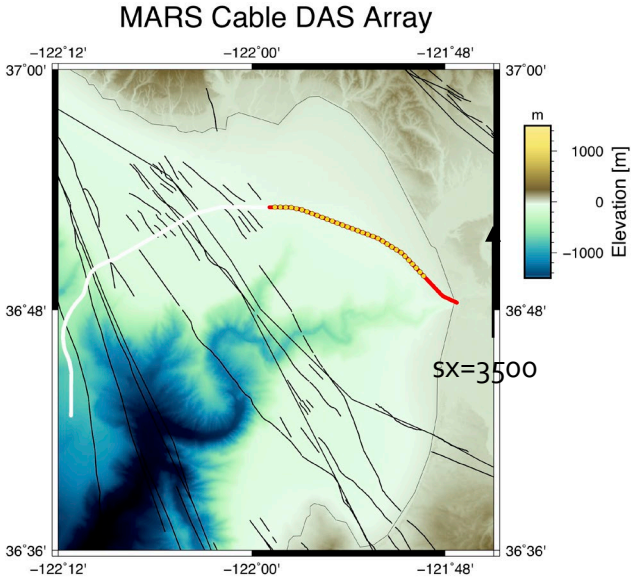


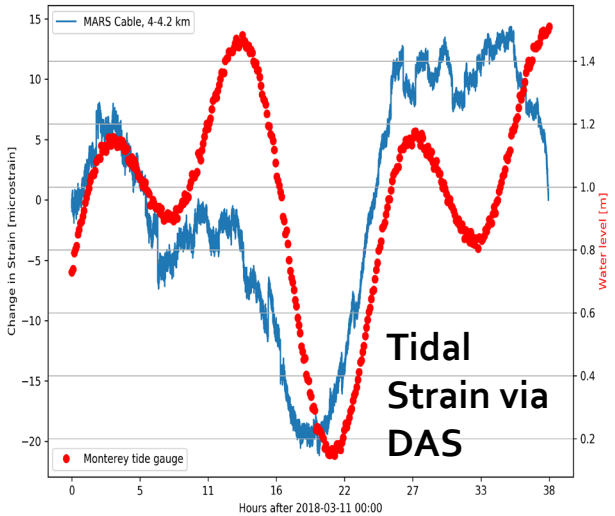
[2 m channel spacing, 10 m gauge, 20 km array, 10 k channels, 500 hz recording, **Densest OBS recording ever?**]

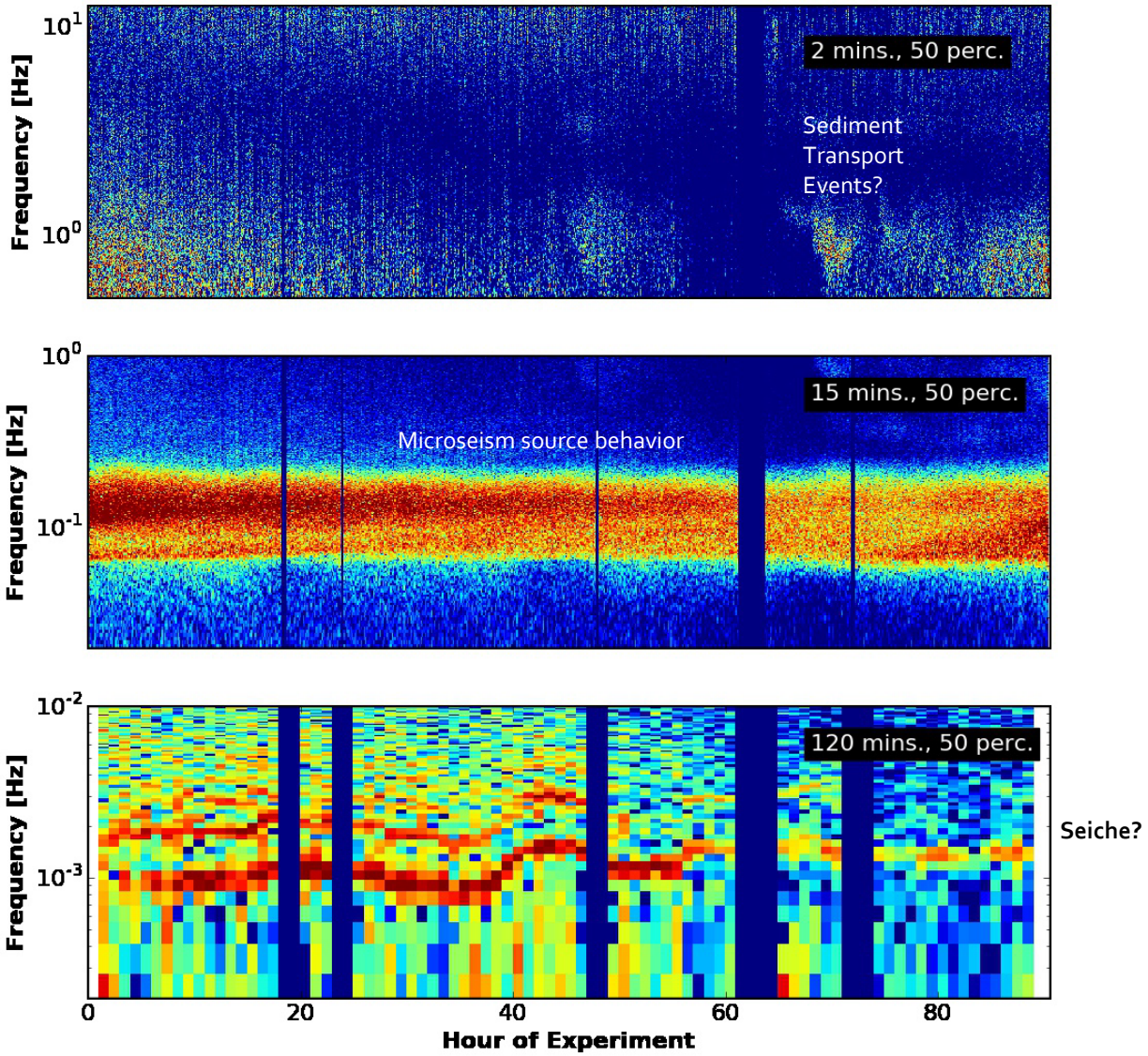


Oceanographic Process Observations via Seafloor DAS?

- Surprisingly broadband (mHz to 100 Hz)
- Signal of oceanic wave processes down to the mHz range (1000 s)
- Can see microseism source behavior, infragravity waves (long period swell groups).
- HF noise which might be useful for imaging.
- Storm & tidal signals.
- **A possible GCS target, seafloor bubble emissions**
- **Ambient noise from platform another possibility, or deformation**







Moving Forward

- Initial seafloor DAS data seems to have potential for seismic recording
- Considering source & DAS cable design in the context of initial offshore DAS data (offset, install)
- Exploring options for acquiring offshore GoM DAS cable dataset for continued task 3 exploration (BP cable, other options?)
- Developing persistent multi-purpose source design for water tank testing (Task 2)
- Considering DAS design in context of possible "model" pilot sites (e.g. High Island)
- Exploring ambient noise applications (both near-surface imaging & local noise analysis) for this class of data.

Thanks For Listening!

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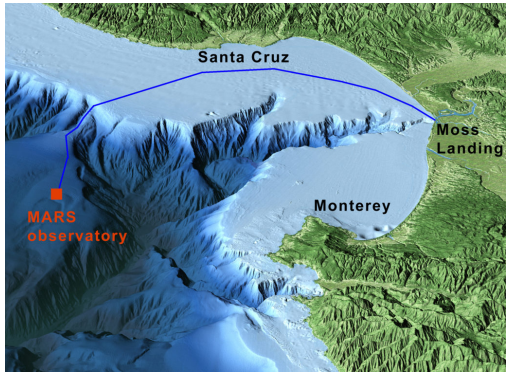
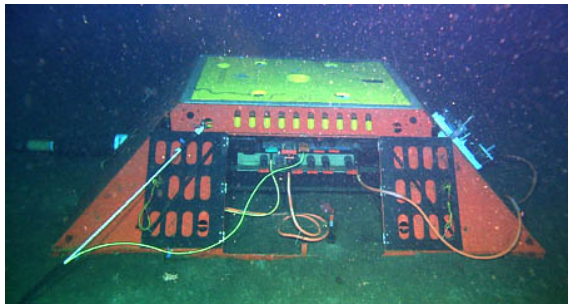
Laboratory Directed Research and Development Program

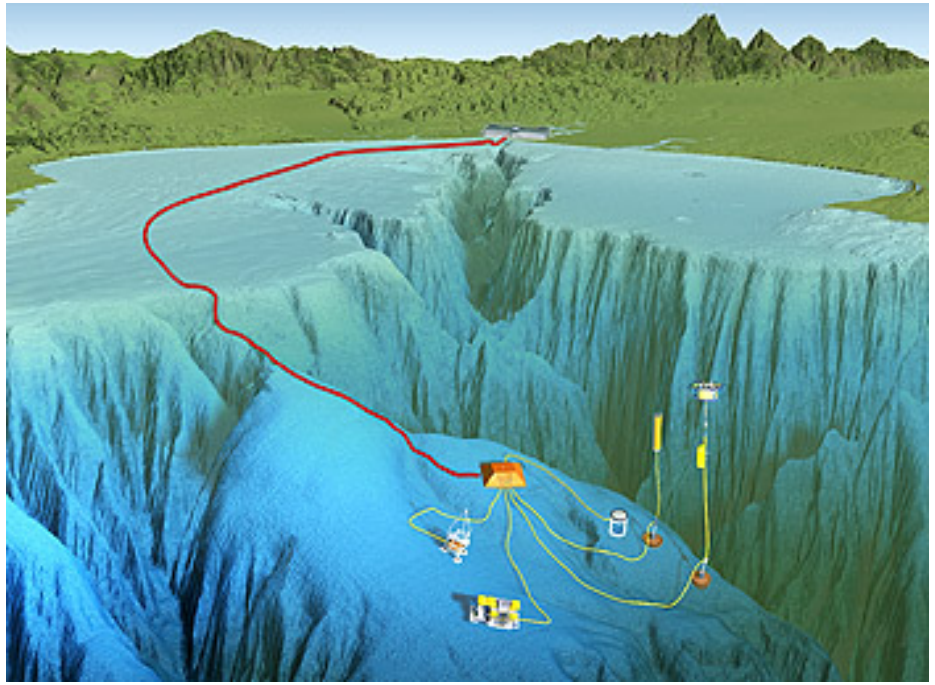
MBARI Acquisition

BACKUP

Ocean bottom seismology is a costly endeavor







Ocean Bottom Seismometer Deployments

NSF 2016 OBS Pool = 247 (37% SP)
European 2014 OBS Pool = 450 (71% SP)
OBS battery life = 14 month +/-6 month
Data Delay (seconds to months)
Annual costs

Cabled Observatories

MARS Cable Laying 2002 – 2007
$11.75M investment
2 GB/s data transfer over 52km